Investment Project Selection with Multi Criteria Decision Making Techniques in FMCG Industry

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ABSTRACT

In today's our modern world, where rivalry is increasing from day to day and technological developments are advancing very fast, decision-making processes are becoming more difficult. Especially for companies, investment projects are a critical decision-making problem due to their huge budgets and their impact on the company. Therefore, making decisions by utilizing scientific methods is of the essence for companies.

Related in the thesis, it is determined to select the most optimum project for the company to invest in a leading company in the FMCG sector based on a project selection problem with 5 main criteria, 8 sub-criteria and 5 alternatives.

In problem solving, AHP, which is the most widely utilized method for weighting criteria in the literature, and TOPSIS, VIKOR, which are the most typically used methods in project selection in the literature, and ARAS method, which is rarely used, were used to address the project selection problem. Since ARAS method studies are impreplance in the literature, it is purposed to fill gap in this thesis is supported by Fuzzy AHP and Fuzzy TOPSIS procedures. In the thesis, it was make firm that the ARAS method, which is scarce used in the literature, works in harmony with the widely used AHP, TOPSIS and VIKOR procedures.

With this Work;

It is forecast that companies can use these mathematical methods to enable decision making in cases involving many criteria and alternatives.

This application in the FMCG sector, where project selection decisions are frequently made, has brought a academic approach to investment project selection problems.

The use of AHP, BAHP in project criteria weighting; TOPSIS, Fuzzy TOPSIS, VIKOR and ARAS methodologies in project selection has make a help to the literature and proved that the methods work in concord with one together. It is estimated that these mathematical modeling can be used in particular decision-making trouble of the company.

Keywords-- Investment Project Selection, Multi Criteria Decision Techniques, AHP(Fuzzy), TOPSIS(Fuzzy), VIKOR, ARAS

I. INTRODUCTION

Decision making is a complex process that involves the ability to evaluate and analyze many different factors. A good decision-making process should involve gathering information, analyzing it, evaluating options and finally making a choice.

Multi-criteria decision-making methods consist of their own algorithms, which are derived so that managers/decision makers can make the most appropriate decision. In the light of the information available, many different algorithms can be used if the algorithms are used to select alternatives. If we have clear information in the decision process, we can easily proceed with classical multi-criteria decision-making methods, but if we do not have clear information, fuzzy multi-criteria decision-making methods have been derived to make a healthy choice in these situations (Rençber, 2022).

In this study, the project selection problem of a company in the FMCG sector, which invests very large budgets every year, is discussed. Within the scope of the literature study, the usage areas and algorithms of MCDM methods have been examined in detail. Considering the literature research, the most widely used AHP and fuzzy AHP methods were used to weight the criteria. In project selection using these values, the most commonly used TOPSIS, Fuzzy TOPSIS and VIKOR methods were used. The ARAS method developed in 2010, which is not widely used in the literature and is used in areas such as project and establishment location selection, has also been used, and it is aimed to contribute to the literature by observing that it works in harmony with other commonly used methods.

II. METHODOLOGY

2.1 Decision and Decision Making

The appropriate response that peoples give when they feel the need to take action is called a decision.

Decision-making consists of the process of choosing the reaction to be given and in this process,

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different alternatives are analyzed, and the most appropriate option is tried to be determined.

2.2 Decision and Decision Elements

Decision Problem: A problem can be defined by the difference between the current situation and the hoped-for situation. The concept of problem is subjective, some may fear the event while others may see it as an opportunity. It is important to think and analyze the decision problem well, this is the biggest factor in solving the problem (Cengiz, 2012).

Decision Maker: The person or persons who will take a decision.

Objective: Setting a goal is very important for making a decision. Alternatives and criteria should be created in line with this goal. The objective should be expressed in a concise and easily understandable way, away from complex definitions. A properly defined objective not only indicates the desired results, but also the obstacles that should not exist in order to achieve them (Cengiz, 2012).

Alternatives: These are the events from which we can choose in order to realize the purpose of decision making (A., 2007).

Criteria: They serve to ensure that options are compared with each other. They are of two types;

Quantitative Criteria: These are the criteria specified by numerical expressions.

Qualitative Criteria: They cannot be expressed numerically. They are criteria where ordinal preferences can be expressed (Cengiz, 2012).

2.3 Decision Making Problem and Process

The first condition for a decision-making problem is the existence of a diversity of alternatives. If there is only one alternative, there is no need to make a choice and proceed with that alternative. At the same time, the problem should have a goal and the results should vary according to the alternatives chosen in line with this goal. In problems with a diversity of alternatives, selecting the optimum option and choosing the best one from alternatives combined in various ways can also be examined within the scope of decision making (Güngör & Özcan, 2022).

2.4 Multi Criteria Decision Making

Multi-criteria decision making (MCDM) problems require at least two criteria and at least two different solutions. In such problems, we encounter discrete situations where the number of alternatives is limited and clearly defined. MCDM problems have a predetermined number of alternatives and the success rate of these alternatives is known in advance. Such problems are selection problems rather than design problems.

In general, MCDM problems require information to determine the relative importance of criteria. These importance weights can be determined by the decision maker himself/herself or by different methods. To develop better scenarios, both verbally (subjective) and numerically (quantifiable), 12 MCDM methods are used. The MCDM problems can be easily expressed in a matrix called a decision matrix, with alternatives in rows and criteria in columns (Cengiz, 2012). The methods used in this study can be considered as AHP, TOPSIS, VIKOR and ARAS, which are suitable for the problems of MCDM.

In this study, 6 different methods were used. AHP and BAHP were used for weighting and TOPSIS, Fuzzy TOPSIS, VIKOR, ARAS methods were used to select the most suitable project. The flow followed in the study is given below (Figure 1).

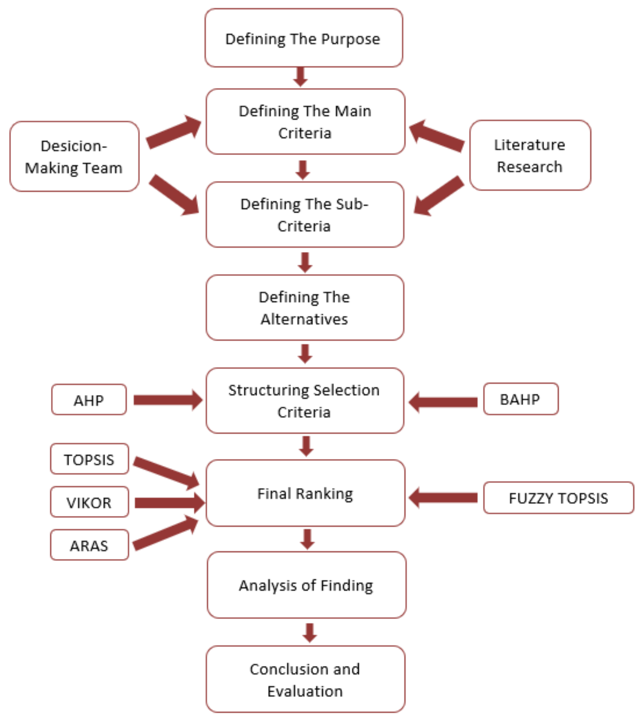

Figure 1: Flow followed in the study

III. PRIOR APPROACH

3.1 AHP (Analytic Hierarchy Process)

The AHP method is preferred because it is a very useful method that blends qualitative and quantitative criteria in the analysis of alternatives if subjective criteria are important by taking into account the subjective criteria in making multi-criteria decisions. In this way, the decision maker can transform subjective preferences into an objective structure (Rouyendegh, 2010).

The solution steps of the AHP method application are as follows (Yaralıoğlu, 2010):

Step 1: This step is the problem definition step and consists of two stages. First, the decision points are identified and then the criteria affecting the decision points

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are identified. For a consistent study, this step is the most important step among all steps of the AHP method.
Number of decisions = m,
Decision point = n

Step 2: In matrices where the criteria are compared pairwise, the diagonal values are written as 1, since the diagonals always correspond to the comparison of the factors with themselves. The comparison matrix is created by querying the superiority of the criteria over each other.

$$A=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}_{nxn}$$

The AHP base scale importance scale in Table 1 is used in these comparisons.

Table 1: İmportance Scale

Importance Values	Value Definitions
1	If both factors are of equal importance
3	If the first factor is more important than the second factor
5	If the first factor is more important than the second factor
7	If the first factor has a very strong importance compared to the second factor
9	If the first factor has an absolute superior importance over the second factor
2,4,6,8	Intermediate values

In cases where the inverse is taken while creating this matrix, the matrix is filled based on the formula;

$$a_{ji} = \frac{1}{a_{ij}}$$

Step 3: Using formulas B_i and b_{ij}, the individual weights of all criteria are determined and column B is created, the relative importance ranking between the factors is determined and the criteria weights for the total impact of the factors are calculated.

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ \dots \\ b_{n1} \end{bmatrix}_{nx1}$$

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

This step has to be repeated for each criterion and in this way the vector B is obtained for n factors, and these vectors are combined to form the matrix below.

$$C=\begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n1} & \dots & b_{nn} \end{bmatrix}_{nxn}$$

According to this matrix, column W of the priority vector is obtained by averaging all values in the column with the weights of the criteria. Obtaining the priority vector is as follows;

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

Step 4: Since the AHP method relies on the consistency of the decision maker's one-to-one comparisons between factors, consistency measurement is required for the realism of the results. AHP uses the Consistency Ratio (CR) for consistency measurement. A Consistency Ratio of 0.10 or less represents an acceptable level of consistency to proceed with the solution of the problem (Saaty, 1988).

The AHP method calculates the Consistency Ratio by comparing a coefficient with the Base Value (λ), which obtains the column vector D by matrix multiplication of the number of factors, the comparison matrix A and the priority vector W.

$$D=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ \\ \\ \\ \\ w_n \end{bmatrix}$$

$$E_i = \frac{d_i}{w_i} (i = 1,2, \dots n)$$

Following the process outlined in the formula, the base value (E) is calculated for each criterion by dividing the i components of the column vector D and the priority vector W by each other. Then, using the arithmetic mean with these values, the base value (λ) is calculated.

$$\lambda = \frac{\sum_{i=1}^{Nn} E_i}{w_i} (i = 1,2, \dots., n)$$

Consistency Indicator (CI) is calculated with the formula;

$$Cl = \frac{\lambda - n}{n - 1}$$

The CR result is obtained by dividing the CI by the appropriate value according to the number of criteria in the Random Indicator (RI) standard.

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Table 2: RI Values

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,525	0,882	1,115	1,252	1,341	1,404	1,452	1,484

$$CR = \frac{CI}{RI}$$

If the CR value is less than 0.10, we can use these criterion weights consistently, if it is greater than 0.10, the whole process should be applied again by reviewing the importance weights starting from step 1.

Step 5: Each factor is assigned a percentage importance level at m decision points. In this step, the percentage distribution of the importance of each factor is determined using head-to-head comparisons and matrix operations over many factors as in the previous step. After each comparison, a column vector S is calculated, which represents the percentage distribution of the evaluated criterion across the decision points. This S-column vector is calculated using the methods described below and indicates the importance of the factors at the decision points. In this way, the percentage significance levels of the decision points of each factor are determined and the necessary distributions are obtained to calculate the total impact of the factors.

$$S_i = [s_{ji}]_{mxl} \quad i = 1,2, \ldots n; j = 1,2, \ldots, m$$

Step 6: A decision matrix is created based on Step 5.

$$K = [s_{ij}]_{mxn}$$

Finally, the K and W vectors are multiplied by each other to obtain the percentage distributions at the decision points in formula;

$$[s_{ij}]_{mxn} x [w_i]_{nxl}$$

3.2 Fuzzy AHP (Analytic Hierarchy Process)

In the case of the AHP method, although expert opinions are taken into account, they cannot reflect the person's way of thinking. The feature that distinguishes BAHP from the AHP method is that it reflects the person's way of thinking, while AHP reveals clear values. In the BAHP method, comparisons are made within a value range (Ertugrul, 2007).

Table:. Saaty's triangular fuzzy numbers (1-9 scale)

Verbal Importance	Fuzzy Scale	Reciprocal Scale
Equal importance	(1,1,1)	(1/1,1/1,1/1)
A little too much importance	(1,3,5)	(1/5,1/3,1/1)
Strong severity	(3,5,7)	(1/7,1/7,1/3)
Very strong severity	(5,7,9)	(1/9,1/7,1/5)
Totally of utmost importance	(7,9,9)	(1/9,1/9,1/7)

Fuzzy AHP application steps are defined below.

Adım 1:

Fuzzy synthetic degree values,

$$S_i = \sum_{j=1}^{m} M_{g_i}^j x \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$$

$$\sum_{j=1}^{m} M_{g_i}^j$$

, to create,

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right), i = 1,2, \ldots, n$$

Let us perform the fuzzy addition of the matrix above.

$$[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j]^{-1}$$

to create,

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

, to create M^j_{gi} (j = 1,2,….,m) Let's calculate fuzzy addition. Then,

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right),$$

$$\left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

Let's get the inverse of the vector.

Step 2:

Proportional expression $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ of M_2'nin M_1, i.e the preference of M_2 over M_1;

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(x)\right)\right]$$

The following expression is then obtained.

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & m_2 \geq m_1 \quad ise \\ 0, & l_1 \geq u_2 \quad ise \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & diğer\ durumlarda \end{cases}$$

Here d is the ordinate of D, the highest point of intersection between μ M_1μ and μ M_2.

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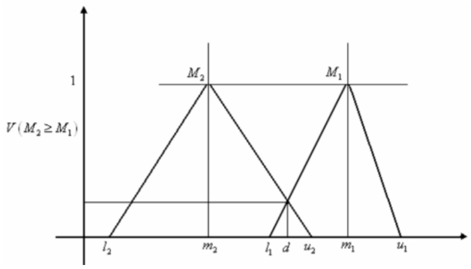

Figure 2: The intersection of M1 and M2

In order to compare M1 and M2, V(M1 ≥ M2) and V(M2 ≥ M1) values are required.

Step 3: In this study, the scale in Table 2.1 is used to rank the triangular fuzzy numbers in the BAHP method. The probability degree of a convex fuzzy number is assigned to a convex fuzzy number greater than k. In this case, the convex fuzzy number can be evaluated within the probability degrees and a ranking can be made according to the criteria.

M_i=(1, 2,, k),

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) ve (M \geq M_2) ve ... ve (M \geq M_k)]$$
$$= \min V(M \geq M_i), \quad i = 1,2,3,...,k$$

can be defined with.

$d'(A_i) = \min V(S_i \geq S_k)$

the weight vector of k,n = 1,2, where k ≠ i;

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T$$

is given by. Here, Ai (i = 1, 2...,n) is n elements.

Step 4: Normalized weight vectors;

$$W = (d(A_1), d(A_2), ..., d(A_n))^T$$

W is not a fuzzy numerical value (Kahraman, 2004).

3.3 Topsis Method

TOPSIS is widely used because it involves simple calculations in execution time by considering ideal and counterfactual solutions (Yalcıner A. Y., 2020). Topsis was first proposed by Hwang and Yoon in 1981. The logic of Topsis is to define an optimum and a non-optimal solution. An optimal solution is one that maximizes the benefit (+) criterion and minimizes the cost (-) criterion. A non-optimal solution converts the cost criterion into a maximum profit criterion. The logic is that the selected alternative is closest to the solution that provides the benefit, i.e., the optimum value, and farthest from the non-optimal value. The ranking of alternatives is based on the "relative similarity to the ideal solution" approach **(**Çitli, 2006).

The application steps of the TOPSIS method are described below;

Step 1: Create a decision matrix (A), which contains the values of the decision points listed in the rows of the decision matrix and the evaluation factors used in the decision in the columns. Matrix A is an original matrix created by the decision maker and is as follows:

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

M decision points in the matrix Aij, n is the number of evaluation criteria (Yaralıoğlu, 2010)**.**

Step 2: A normalized decision matrix is created based on matrix A.(R) Formula (2) is used.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad i=1,...,m \quad j=1,...,n$$

The R matrix is calculated using formula (3).

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

Step 3: Weighted Decision Matrix (V) Formation

After determining the weighted values $\left(\sum_{j=1}^{n} w_j = 1\right)$, the matrix V is created with R.

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w\, r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 4: Calculating the Optimum (A^+) and Non-Optimum (A^-) Solution in this step;

The maximum and minimum values in the standard weighted decision matrix are defined. A^+ = maximum values, A^- = minimum values.

$$A^+ = \{v_1^+, v_2^+, ..., v_n^+\}$$
$$A^- = \{v_1^-, v_2^-, ..., v_n^-\}$$

Step 5: Calculation of Distances between Alternatives; After determining the ideal values, distances are calculated according to the optimum and non-optimal solution.

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$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2} \qquad \text{i=1,2,…,m}$$

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2} \qquad \text{i=1,2,…,m}$$

The numbers Si^+ and Si^- are equal to the number of decision points.

Step 6: Relative Proximity Calculation for the Ideal Solution; The approximation (Ci) of all decision points to the optimum solution is calculated with the measures of the distance to the optimum and non-optimal solution. It is the ratio of the non-optimal measure in the total measure. It is calculated by relative approximation to the optimum solution.

$$C_i^+ = \frac{S_i^-}{S_i^- + S_i^+} \qquad \text{i=1,2,…,m}$$

Ci^+ is between 0<=1<=Ci^+. Importance ranks are determined by ranking the values from largest to smallest.

3.4 Fuzzy Topsis Method

In cases where numerical values are insufficient, different methods have been derived using the TOPSIS method with fuzzy numbers. The method developed by Chen and Hwang in 1992 uses trapezoidal fuzzy numbers. In addition, other methods using fuzzy triangular numbers have been developed subsequently. These methods provide a more comprehensive solution for measuring human judgment when numerical values are missing (Liang, 1999).

The method is based on the work of Chen and Hwang (1992). Fuzzy and non-fuzzy numbers can be used in the TOPSIS method. Fuzzy numbers can be triangular or trapezoidal.

Fuzzy Topsis method solution steps are defined below.

Table 3: Triangular Fuzzy Numbers of Verbal Variables Used in Alternative Evaluation (CHEN, 2000) (Linguistic variables for ratings)

Verbal Variable	Trianngular Fuzzy Number
Very Poor (ÇK)	(0,0,1)
Bad (K)	(0,1,3)
A Little Bad (BK)	(1,3,5)
Medium (O)	(3,5,7)
Somewhat Good (Bİ)	(5,7,9)
Good (İ)	(7,9,10)
Very Good (Çİ)	(9,10,10)

The importance weights of criteria can be obtained directly or indirectly. They can be obtained by assignment or indirectly by using a pairwise comparison matrix.

In a decision group of K people, the rating of the alternatives of each criterion and the importance of the criteria,

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^1 (+) \tilde{x}_{ij}^2 (+) \ldots (+) \tilde{x}_{ij}^K\right]$$

$$\tilde{w}_j = \frac{1}{K}\left[\tilde{w}_j^1 (+) \tilde{w}_j^2 (+) \ldots (+) \tilde{w}_j^K\right]$$

Is calculated.

Here, x^K_{ij} and w^K_j are the importance weight and rating of K . decision makers.

A fuzzy FCDM problem in matrix format,

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

$$\tilde{W} = \left[\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n\right]$$

is calculated as. x_{ij} for $\forall_{ij}$, and w_j for j=1,2,....n are qualitative variables. The qualitative variables are defined using triangular fuzzy numbers as $x_{ij}=(a_{ij}, b_{ij}, c_{ij})$ and $wj=(w_{j1}, w_{j2}, w_{j3})$. To make the scales of the criteria comparable, a linear scale transformation is adopted. This results in a normalized fuzzy decision matrix denoted by R;

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m \times n}$$

B is a set of benefit criteria, C is a set of cost criteria;

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{c_{ij}}\right), j \in C$$

$$c_j^* = \max_i c_{ij} \quad j \in B$$

$$a_j^- = \min_i a_{ij} \; j \in C$$

The above-mentioned normalization method places the values of the normalized triangular fuzzy numbers in the range [0,1]. Normalized weighted fuzzy decision matrix that takes into account the different importance of all criteria,

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m \times n}, i = 1,2,\ldots,m \;\; , j = 1,2,\ldots,n$$

is constructed as Here, $v_{ij} = r_{ij}(.)w_{ij}$

In the weighted normalized matrix, the values vij, ∀i, j are triangular expressions and are in the range [0,1].

An uncertain optimum outcome (A^*) and an uncertain negative optimum outcome (A^-),

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\right),$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right)$$

is defined as.

Here, $v_j^* = (1,1,1,1)$ and 1,1,1,1 $v_j^- = (0,0,0)$ j = 1, 2,.....,n.

The distance of all alternatives from fuzzy A^* and fuzzy A^- values.

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) \ , \ i = 1,2,\ldots,m$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \ , \ i = 1,2,\ldots,m$$

d (.,.) is the value of the distance between the fuzzy numbers.

The closeness coefficient of each alternative is used to determine the position of each alternative in the ranking;

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \ , \ i = 1,2,\ldots,m$$

Is calculated.

As CC_i converges to 1, alternative Ai moves away from the fuzzy (-) ideal and approaches the fuzzy (+) ideal solution (A^*)

The algorithm of the Fuzzy Topsis method can be listed as follows;

Step 1: Evaluation criteria are defined by forming a team of experts.

Step 2: Linguistic ratings for all alternatives are selected according to appropriate verbal variables and criteria that indicate the importance of the criteria.

Step 3: The weights of the criteria are combined to obtain the combined weight w_j of criterion C_j and the decision makers' opinions are combined with the fuzzy x_{ij} value of the choice Ai under criterion C_j.

Step 4: The normalized fuzzy decision matrix and fuzzy matrix are generated.

Step 5: A weighted normalized fuzzy decision matrix is generated.

Step 6: Fuzzy optimum and fuzzy negative optimum solutions are determined.

Step 7: We calculate the distances of the fuzzy positive and fuzzy negative ideal solution alternatives.

Step 8: Proximity coefficients are calculated for each option.

Step 9: The options are ranked according to the defined degree of closeness.

3.5 Vikor Method

VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) is a method developed for multi-criteria optimization of complex structures. In this context, it is a method that allows to determine a compromise ranking and to reach a compromise solution with defined weights. It refers to selecting the most appropriate one by ranking alternatives according to opposite criteria. The VIKOR method considers a multi-criteria investment index based on proximity to the ideal solution. Problem solving based on compromise with conflicting criteria helps decision makers reach a decision. Opricovic and Tzeng proposed the VIKOR method for multi-criteria optimization of complex problems in 2004 (S. Opricovic and G.-H. Tzeng, 2004).

The VIKOR method is particularly useful in multi-criteria decision-making when decision-makers have difficulty making choices or explaining their choices (Paksoy, 2015).

The stages of application of the VIKOR method are explained as follows.

Step 1:

Find the values of f_i^* (max.) and f_i^- (min.) specific to the criteria. i= utility criterion.

if i=1,2, 3..., n;

$$f_i^* = max_j f_{ij}$$

$$f_i^- = min_j f_{ij}$$

functions are created.

Step 2:

By determining the comparison values Sj and Rj, Sj and Rj defined for j= 1, 2..., n, the optimum value and the worst value are generated according to the jth alternative.

$$s_j = \sum_{i=1}^{n} w_i \, (f_i^* - f_{ij})/(f_i^* - f_i^-)$$

$$R_j = max_i \, [\frac{w_i(f_i^* - f_{ij})}{f_i^* - f_i^-}]$$

The w_i(weight) of each criterion in the equations should be 1 in total.

Step 3:

With the formulas below, Q_j is found for j = 1, 2..., n values.

$$Q_j = \frac{v(S_j - S^*)}{S^- - S^*} + (1 - v)(R_j - R^*)/(R^- - R^*)$$

$$S^* = min_j S_j \text{ve} S^- = max_j S_j$$

$$R^* = min_j R_j \text{ve} R^- = max_j R_j$$

The value of v in the equations gives the weight that provides the greatest benefit according to the intention, and the value (1-v) gives the weight of regret (providing the least benefit).

Step 4:

The values specific to S, R and Q are all ranked in descending order, thus determining the rankings of the three values.

Step 5:

The optimal (a') "compromise" solution with respect to the value of Q is determined when the following two conditions are met.

First condition: "Acceptable utility", a is the second alternative with respect to Q. Equivalent DQ where J is an alternative number is calculated by the formula DQ = 1/(J-1).

$$Q(a'') - Q(a') = DQ$$

Secondary condition: "Acceptable decision stability", as in the Q ranking, in at least one ranking according to the value of R or S, alternative a' must be the best choice.
Alternatives a' and a" where only the first condition is satisfied and a',a",.....,an where only the second condition is satisfied are called "compromise solutions".

In the inequality Q(an) - Q(a') < DQ, the maximum value of n produces alternative a. When all steps of the method are applied, the best alternative is determined in descending order. The resulting ranking is called a "matching" ranking. The VIKOR method also provides a somewhat "compromised" solution (Ertuğrul, 2009).

3.5 Aras Method

ARAS methodology was developed by Zavadskas and Turksis in 2010 as a brand new method for solving complex problems. This method is based on simple relative comparisons. Although ARAS methodology is preferred in Northern European regions, it has recently started to be used outside Europe (Altın, 2020).

In the ARAS method, the utility function chosen to determine the relative impact of the options available in the project is directly proportional to the relative impact of the weights and values of the criteria. The ARAS methodology allows the determination of alternative performance and reveals the relative similarity of all alternatives to the optimal alternative (Dadelo, 2012).
The Aras Method is implemented in 5 steps.

Step 1: Decision matrix formation

It consists of Alternatives (rows) and Criteria (columns).

$$X = \begin{bmatrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}; \; i = 0,1,\ldots,m \; ; \; j = 1,2,\ldots,n$$

M = number of alternatives, n = number of criteria, xij = performance value of alternative i with respect to criterion j, x0j = optimal value of criterion j. If the optimal value of criterion j is unknown, formula is used:

$$\begin{cases} Eğer \;\; \underset{i}{maks}\, x_{ij} \;\; ise \;\; x_{0j} = \underset{i}{maks}\, x_{ij} \\ Eğer \;\; \underset{i}{\min}\, x_{ij}^{*} \;\; ise \;\; x_{0j} = \underset{i}{\min}\, x_{ij}^{*} \end{cases}$$

Step 2: Normalization

The purpose of normalization is to standardize criteria with different dimensions by performing a normalization process. The criteria are all in the range [0,1].

In the normalization process, first formula is used for the criteria targeted to be the highest and second formula is used for the criteria targeted to be the lowest.

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}$$

$$\bar{x}_{ij} = \frac{1/x_{ij}}{\sum_{i=0}^{m} 1/x_{ij}}$$

The normalized decision matrix is constructed as follows:

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \bar{x}_{02} & \cdots & \bar{x}_{0n} \\ \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{bmatrix}; \; i = 0,1,\ldots,m \; ; \; j = 1,2,\ldots,n$$

Step 3: Constructing the weighted normalized decision matrix.

In this step, a weighted normalized decision matrix is created. Criteria weights range from 0 to 1 ($0 < w_{ij} < 1$). The sum of the criteria weights should be equal to 1. Normalized weights are determined by formula (6). In the formula, w_{ij} represents the weight (significance level) of criterion j and x_{ij} represents the normalized value of criterion j.

$$x_{ij} = \bar{x}_{ij} w_j \,; \qquad i = 0,1,\ldots,m$$

The weighted normalized decision matrix is constructed as shown below:

$$X = \begin{bmatrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}; \qquad i = 0,1,\ldots,m \; ; \; j = 1,2,\ldots,n$$

Step 4: Calculation of the optimality function

$$S_i = \sum_{j=1}^{n} x_{ij} \,; \qquad i = 0,1,\ldots,m$$

In formula (8), Si is the fitness function of alternative i. S_i is related to the values of xij and wj that affect the final outcome. If the S_i value of an alternative is large, it is identified as the most effective alternative.

Step 5: Determining the degree of utility and ranking.
The degree of utility is determined by comparing the optimal function of the alternatives with the optimal function value of the best option. Although S_0 is the best value of the optimal function, the calculation is done by formula (9).

$$K_i = \frac{S_i}{S_0} \,; \qquad i = 0,1,\ldots,m$$

3.6 Studies in the Literature on the use of CRM Methods

The literature was searched in detail and some theses/articles in which AHP, TOPSIS, VIKOR, ARAS methods were used were listed.

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Table 4: The studies in the literature in which the CRM methods are used are listed

Author	Thesis / Article Topic	Methods
Çağın KARABIÇAK, Burcu ÖZCAN, Mehlika KOCABAŞ AKAY	Supplier Selection	AHP / BAHP
Gizem FİLİZ TÜRKMEN	R&D Project Selection	AAS / ANP
AHMET OZAN SÖYLEYİCİ	Supplier Selection	BULANIK TOPSIS
Tuerxunmaımaıtı YILIZATI	Supplier Selection	AHS / TOPSİS
Ayşe YILDIZ	Project Selection	VIKOR
Tuğçe KARATEKE	ERP Software Selection	AHP
Büşra BEKİ	Project Selection	TOPSİS
Burak KARAMAN, Hakan ÇERÇİOĞLU	Project Selection	VIKOR / AHP
Burcu ÖZCAN, Elif YILMAZER	İnvestment Project Selection	AHP
Bahri UÇAKÇIOĞLU, Tamer EREN	İnvestment Project Selection	VIKOR / AHP
Tuba YAKICI AYAN, Selçuk PERÇİN	R&D Project Selection	BULANIK TOPSIS
Duygu CENGİZ	Project Selection	AHP, TOPSIS
Danışment VURAL, Erkan KÖSE, Burcu BAYAM	Personnel Selection	AHP, VIKOR
Engin KARAKIŞ	Project Selection	BULANIK AHP/BULANIK TOPSIS
Deniz PEKER	Project Selection	AHP, TOPSIS
Türkan Melis PEKER	Project Selection	AHP, VIKOR,ARAS
Mohammad M RAHMAN, Kazi B AHSAN	Supplier Selection	AHP, BAHP
Amoah Daniel AYİSİ, Ming YİN	Service Provider Selection	TOPSIS

IV. OUR APPROACH

This study deals with the investment project selection of a leading company in the FMCG sector. The objective of the study is to select the most suitable alternative for the firm. The main criteria and sub-criteria in the company's project selection problem are listed in Figure 3, 5 main criteria as well as 8 sub-criteria are listed.

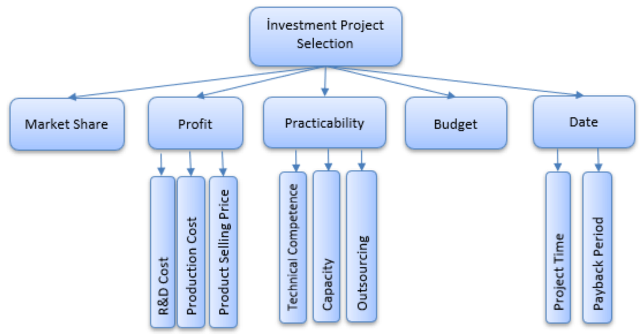

Figure 3: Sub and Main Criteria for Project Selection

4.1 AHP Progressive

The weights of the criteria determined by expert decision maker opinions and literature research were determined by AHP method as follows. Comparison matrices were created based on the main criteria and sub-criteria. Finally, the consistency ratio was checked and it was found to be less than 0.10 for all criteria. Accordingly, it was seen that the determined criterion weights are appropriate to be used in project selection. The implementation steps are given below;

4.1.1 Main criteria comparison matrix

K1: Market share; how much the product sells in the market and how much our company can take place in the market.

K2: Profit; profit is analyzed by considering production cost, R&D cost and sales cost.

K3: Applicability; the suitability of the company's technical competence and production capacity are evaluated.

K4: Investment budget; refers to the total budget to be spent on the project.

K5: Time; project completion time and ROI are evaluated.

Table 5: Comparison matrix

	K1	K2	K3	K4	K5
K1	1	2	3	7	9
K2	0,5	1	3	5	7
K3	0,3333	0,3333	1	2	5
K4	0,1429	0,2	0,5	1	2
K5	0,1111	0,1429	0,2	0,5	1
Total	2,0873	3,6762	7,7	15,5	24

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Table 6: Normalized matrix

	K1	K2	K3	K4	K5	Criteria Weights
K1	0,4791	0,544	0,3896	0,4516	0,375	0,4479
K2	0,2395	0,272	0,3896	0,3226	0,2917	0,3031
K3	0,1597	0,0907	0,1299	0,129	0,2083	0,1435
K4	0,0684	0,0544	0,0649	0,0645	0,0833	0,0671
K5	0,0532	0,0389	0,026	0,0323	0,0417	0,0384

Table 7: Priority vector matrix

	K1	K2	K3	K4	K5	Core Values	Total Criteria	Lamda	CI	RI
K1	0,45	0,61	0,43	0,47	0,35	2,3	5,14	5,084	0,021	0,019
K2	0,22	0,3	0,43	0,34	0,27	1,56	5,15			
K3	0,15	0,1	0,14	0,13	0,19	0,72	5,02			
K4	0,06	0,06	0,07	0,07	0,08	0,34	5,07			
K5	0,05	0,04	0,03	0,03	0,04	0,19	5,05			

For the criteria weights to be consistent and used, the value of 0.0189 must be less than 0.10. Since the control is ensured, the weights of criteria K1,K2,K3,K4 can be used.

4.1.2 Comparison matrix of sub-criteria of the main criterion of practicability:

The criteria weights of the technical competence, capacity, outsourcing sub-criteria determined based on the main criteria of applicability are as follows.

K1: Technical competence
K2: Capacity
P3: Outsourcing

Table 8: Comparison matrix

	K1	K2	K3
K1	1	2	6
K2	0,5	1	4
K3	0,1667	0,25	1
Toplam	1,6667	3,25	11

Table 9: Normalized matrix

	K1	K2	K3	Criteria Weights
K1	0,6	0,6154	0,5455	0,5869
K2	0,3	0,3077	0,3636	0,3238
K3	0,1	0,0769	0,0909	0,0893

Table 10: Priority vector matrix

	K1	K2	K3	Core Values	Total Criteria	Lamda	CI	RI
K1	0,59	0,65	0,54	1,77	5,14	5,084	0,021	0,019
K2	0,22	0,3	0,43	1,56	5,15			
K3	0,15	0,1	0,14	0,72	5,02			

For the criteria weights to be consistent and used, the value of 0.0877 must be less than 0.10. Since the control is ensured, the weights of criteria K1,K2,K3,K4 can be used.

4.1.3 Comparison matrix of sub-criteria of the main criterion of date:

The criteria weights of the payback period and project duration sub-criteria, which are determined based on the time main criteria, are as follows

K1: Payback period
K2: Project duration(time)

Table 11: Comparison matrix

	K1	K2
K1	1	3
K2	0,3333	1
Toplam	1,3333	4

Table 12: Normalized matrix

	K1	K2	Criteria Weights
K1	0,75	0,75	0,75
K2	0,25	0,25	0,25

Table 13: Priority vector matrix

	K1	K2	Core Values	Total Criteria	Lamda	CI	RI
K1	0,75	0,75	1,5	1,5	2	0,000001	0,0010
K2	0,25	0,25	0,5	0,5			

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4.1.3 Comparison matrix of sub-criteria of the main criterion of profit:

The criteria weights of the R&D cost, production cost and sales price sub-criteria, which are determined based on the main profit criteria, are as follows
K1: R&D cost
K2: Production cost
K3: Product Selling price

Table 14: Comparison matrix

	K1	K2	K3
K1	1	2	5
K2	0,5	1	3
K3	0,2	0,3333	1
Toplam	1,7	3,3333	9

Table 15: Normalized matrix

	K1	K2	K3	Criteria Weights
K1	0,5882	0,6	0,5556	0,5813
K2	0,2941	0,3	0,3333	0,3092
K3	0,1176	0,1	0,1111	0,1096

Table 16: Priority vector matrix

	K1	K2	K3	Core Values	Total Criteria	Lamda	CI	RI
K1	0,58	0,61	0,55	1,7475	3,0064	3,0037	0,0018	0,0352
K2	0,29	0,31	0,33	0,9285	3,0035			
K3	0,11	0,10	0,11	0,3289	3,0012			

The weight values of the main and sub-criteria were determined, and then the weight values of the main criteria were multiplied by the calculated weight values of the sub-criteria to obtain a common global weight value and the study proceeded based on these weight values.(Peker, 2014)

Table 17: Main Criteria and sub-criteria are listed according to the AHP method

Main Criteria	Local Weight	Sub-main Criteria	Local Weight	Overall Weight
Market Share	0,4479	-	-	0,4479
Profit	0,3031	R&D Cost	0,5813	0,1762
		Production Cost	0,3092	0,0937
		Production Selling Price	0,1096	0,0332
Practicability	0,1435	Technical Competence	0,5869	0,0842
		Capacity	0,3238	0,0465
		Outsourcing	0,0893	0,0128
Budget	0,0671	-	-	0,0671
Date	0,0384	Project Time	0,75	0,0288
		Payback Period	0,25	0,0096

Table 18: Criteria weights are listed in descending order

Criteria		Weight
x1	Market share	0,4479
x2	R&D Cost	0,1762
x3	Product Cost	0,0937
x4	Technical Competence	0,0842
x5	Budget	0,0671
x6	Capacity	0,0465
x7	Product Selling Price	0,0332
x8	Project Time	0,0288
x9	Outsourcing	0,0128
x10	Payback Period	0,0096

4.2 Aras Method Progressive

Using the criteria weights determined by the AHP method, project selection / ranking was made for 5 projects (a1, a2, a3, a4, a5) determined for the company with the aras method. The decision matrix of the criteria was created and it was determined whether they were benefit-oriented (+) or cost-oriented (-). Accordingly, the optimum values for each criterion were determined.

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Table 19: Decision matrix where optimum values are determined

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
OPTİMUM	7	4	5	6	175000	101092	8	1	2	2
a1	7	8	7	5	175000	30000	8	2	4	2
a2	5	4	5	6	323300	29806	7	1	3	3
a3	4	5	5	5	430000	101092	6	1,5	2	2,5
a4	4	5	6	5	440000	28910	6	1,5	2	2,5
a5	5	6	9	6	552967	64075	7	2	4	1,5

Table 20: Utility transformed decision matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
OPTİMUM	7	0,1250	0,1111	6	0,0000018	101092	8	1	0,2500	0,3333
a1	7	0,1250	0,1429	5	0,0000057	30000	8	0,5000	0,2500	0,5000
a2	5	0,2500	0,2000	6	0,0000031	29806	7	1,0000	0,3333	0,3333
a3	4	0,2000	0,2000	5	0,0000023	101092	6	0,6667	0,5000	0,4000
a4	4	0,2000	0,1667	5	0,0000023	28910	6	0,6667	0,5000	0,4000
a5	5	0,1667	0,1111	6	0,0000018	64075	7	0,5000	0,2500	0,6667

Table 21: Normalized decision matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
OPTİMUM	0,2188	0,1172	0,1193	0,1818	0,1062	0,2848	0,1905	0,1304	0,1200	0,1266
a1	0,2188	0,1172	0,1533	0,1515	0,3357	0,0845	0,1905	0,1304	0,1200	0,1899
a2	0,1563	0,2344	0,2147	0,1818	0,1817	0,0840	0,1667	0,2609	0,1600	0,1266
a3	0,1250	0,1875	0,2147	0,1515	0,1366	0,2848	0,1429	0,1739	0,2400	0,1519
a4	0,1250	0,1875	0,1789	0,1515	0,1335	0,0814	0,1429	0,1739	0,2400	0,1519
a5	0,1563	0,1563	0,1193	0,1818	0,1062	0,1805	0,1667	0,1304	0,1200	0,2532

Table 22: Weighted normalized matrix decision matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
OPTİMUM	0,0980	0,0206	0,0112	0,0153	0,0071	0,0132	0,0063	0,0038	0,0015	0,0012
a1	0,0980	0,0206	0,0144	0,0128	0,0225	0,0039	0,0063	0,0038	0,0015	0,0018
a2	0,0700	0,0413	0,0201	0,0153	0,0122	0,0039	0,0055	0,0075	0,0021	0,0012
a3	0,0560	0,0330	0,0201	0,0128	0,0092	0,0132	0,0047	0,0050	0,0031	0,0015
a4	0,0560	0,0330	0,0168	0,0128	0,0090	0,0038	0,0047	0,0050	0,0031	0,0015
a5	0,0700	0,0275	0,0112	0,0153	0,0071	0,0084	0,0055	0,0038	0,0015	0,0024

Table 23: Optimality function, degree of utility and ranking matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	Si	Ki Ranking (Si/S0)	Rank
OPTİMUM	0,0980	0,0206	0,0112	0,0153	0,0071	0,0132	0,0063	0,0038	0,0015	0,0012	0,1783		
a1	0,0980	0,0206	0,0144	0,0128	0,0225	0,0039	0,0063	0,0038	0,0015	0,0018	0,1857	1,0412	1,0000
a2	0,0700	0,0413	0,0201	0,0153	0,0122	0,0039	0,0055	0,0075	0,0021	0,0012	0,1791	1,0045	2,0000
a3	0,0560	0,0330	0,0201	0,0128	0,0092	0,0132	0,0047	0,0050	0,0031	0,0015	0,1586	0,8894	3,0000
a4	0,0560	0,0330	0,0168	0,0128	0,0090	0,0038	0,0047	0,0050	0,0031	0,0015	0,1456	0,8164	5,0000
a5	0,0700	0,0275	0,0112	0,0153	0,0071	0,0084	0,0055	0,0038	0,0015	0,0024	0,1528	0,8568	4,0000

As seen in Table 24, the ranking of project selection according to the Aras method is a1 > a2 > a3 > a5 > a4 and Project 1 is selected as the most suitable project to invest in.

4.3 Topsis Method Progressive

Project selection / ranking was made for 5 projects (a1, a2, a3, a4, a5) determined for the company by topsis method using the criteria weights found by AHP method. The decision matrix of the criteria was created and it was determined whether they were benefit (+) or cost (-).

Table 24: Decision matrix identifying cost-benefit aspects

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
a1	7,0000	8,0000	7,0000	5,0000	175000	30000	8,0000	2,0000	4,0000	2,0000
a2	5,0000	4,0000	5,0000	6,0000	323300	29806	7,0000	1,0000	3,0000	3,0000
a3	4,0000	5,0000	5,0000	5,0000	430000	101092	6,0000	1,5000	2,0000	2,5000
a4	4,0000	5,0000	6,0000	5,0000	440000	28910	6,0000	1,5000	2,0000	2,5000
a5	5,0000	6,0000	9,0000	6,0000	552967	64075	7,0000	2,0000	4,0000	1,5000

Table 25: Normalized decision matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
a1	0,6116	0,6209	0,4763	0,4124	0,1933	0,2304	0,5230	0,5443	0,5714	0,3797
a2	0,4369	0,3105	0,3402	0,4949	0,3572	0,2289	0,4576	0,2722	0,4286	0,5695
a3	0,3495	0,3881	0,3402	0,4124	0,4750	0,7765	0,3922	0,4082	0,2857	0,4746
a4	0,3495	0,3881	0,4082	0,4124	0,4861	0,2221	0,3922	0,4082	0,2857	0,4746
a5	0,4369	0,4657	0,6124	0,4949	0,6109	0,4922	0,4576	0,5443	0,5714	0,2847

Table 26: Weighted normalized decision matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
a1	0,2739	0,1094	0,0446	0,0347	0,0130	0,0107	0,0174	0,0157	0,0073	0,0036
a2	0,1957	0,0547	0,0319	0,0417	0,0240	0,0106	0,0152	0,0078	0,0055	0,0055
a3	0,1565	0,0684	0,0319	0,0347	0,0319	0,0361	0,0130	0,0118	0,0037	0,0046
a4	0,1565	0,0684	0,0383	0,0347	0,0326	0,0103	0,0130	0,0118	0,0037	0,0046
a5	0,1957	0,0820	0,0574	0,0417	0,0410	0,0229	0,0152	0,0157	0,0073	0,0027

Table 27: Determination of the worst & best matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
V+ (OPTİMUM)	0,2739	0,0547	0,0319	0,0417	0,0130	0,0361	0,0174	0,0078	0,0037	0,0027
V-	0,1565	0,1094	0,0574	0,0347	0,0410	0,0103	0,0130	0,0157	0,0073	0,0055

Table 28: Euclidean distance from the best (S_i^+) and worst (S_i^-) and determination of ranking

	Si(+)	Si(-)	Performance Score	Rank
a1	0,0626	0,1215	0,6598	1
a2	0,0831	0,0747	0,4733	2
a3	0,1200	0,0558	0,3172	4
a4	0,1231	0,0463	0,2736	5
a5	0,0925	0,0500	0,3507	3

As seen in Table 29, according to the TOPSIS method, the ranking of project selection is a1 > a2 > a5 > a3 > a4 and Project 1 is selected as the most suitable project to invest in.

4.4 Vikor Method Progressive

Project selection / ranking was made for 5 projects (a1, a2, a3, a4, a5) determined for the company with the aras method by using the criteria weights found with the AHP method. The decision matrix of the criteria has been created, it has been determined whether it is benefit (+) or cost (-) and the optimum best and worst values are also indicated in the table.

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Table 29: Decision matrix identifying cost-benefit aspects

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
ORİENT.	+	-	-	+	-	+	+	-	-	-
W	0,4479	0,1762	0,0937	0,0842	0,0671	0,0465	0,0332	0,0288	0,0128	0,0096
a1	7	8	7	5	175000	30000	8	2	4	2
a2	5	4	5	6	323300	29806	7	1	3	3
a3	4	5	5	5	430000	101092	6	1,5	2	2,5
a4	4	5	6	5	440000	28910	6	1,5	2	2,5
a5	5	6	9	6	552967	64075	7	2	4	1,5
BEST	7	4	5	6	175000	101092	8	1	2	1,5
WORST	4	8	9	5	552967	28910	6	2	4	3

Table 30: Sj and Rj are the comparison values for j= 1,2,...,n, where Sj and Rj are the best and worst values for the jth alternative

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	Si	Ri
a1	0,0000	0,1762	0,0468	0,0842	0,0000	0,0458	0,0000	0,0288	0,0128	0,0032	0,3978	0,1762
a2	0,2986	0,0000	0,0000	0,0000	0,0263	0,0459	0,0166	0,0000	0,0064	0,0096	0,4034	0,2986
a3	0,4479	0,0440	0,0000	0,0842	0,0453	0,0000	0,0332	0,0144	0,0000	0,0064	0,6755	0,4479
a4	0,4479	0,0440	0,0234	0,0842	0,0471	0,0465	0,0332	0,0144	0,0000	0,0064	0,7471	0,4479
a5	0,2986	0,0881	0,0937	0,0000	0,0671	0,0238	0,0166	0,0288	0,0128	0,0000	0,6295	0,2986

Table 31. The Q value is calculated by determining the most beneficial (Si) and regret values (Ri)

	Si	Ri	Qi	Rank
a1	0,3978	0,1762	0	1
a2	0,4034	0,2986	0,2333	2
a3	0,6755	0,4479	0,8974	4
a4	0,7471	0,4479	1	5
a5	0,6295	0,2986	0,5569	3
S*R*	0,3978	0,1762		
S-R-	0,7471	0,4479		

Project ranking is done by sorting the calculated Q value from smallest to largest.
To check the accuracy of the result;
The two conditions to be explained must be met;
The most appropriate (a') option in the ranking is referred to as the "compromise" solution.
First condition: The second (a") option in the ranking is called "Acceptable advantage". It is calculated by the formula DQ = 1/(J-1) (J is taken as the number of alternatives).
Q(a'') – Q(a2) = DQ
DQ = 0,25
0,9330 >= DQ control is performed and the first condition is met.
Second condition: When the first selected alternative is analyzed based on R or S values, it must be equal to the best alternative either in R value or in S value.
For a', S_i= 0.3978, R_i=0.1762 and the second condition is met.

The project ranking was determined as a1 > a2 > a5 > a3 > a4. With the VIKOR method, Project 1 was selected as the most appropriate project to invest in.

4.5 Fuzzy AHP Method Progressive

4.5.1 Creation of comparative matrices of main criteria

The comparative decision matrix of the main criteria was determined with triangular fuzzy numbers.

The weights of the criteria determined by the literature and expert opinions were determined as follows with the Fuzzy AHP method in order to reflect the human way of thinking and minimize uncertainty. Comparison matrices were created on the basis of main criteria and sub-criteria.

Table 32: Decision matrix created with triangular fuzzy numbers

	K1	K2	K3	K4	K5
K1	(1,1,1)	(1,3,5)	(1,3,5)	(5,7,9)	(7,9,11)
K2	(1/5,1/3,1)	(1,1,1)	(1,3,5)	(3,5,7)	(5,7,9)
K3	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1,3,5)	(3,5,7)
K4	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)	(1,3,5)
K5	(1/11,1/9,1/7)	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)

Table 33: Fuzzy synthetic(S) decision matrix

	l	m	u
K1	0,1894	0,4147	0,8960
K2	0,1288	0,2945	0,6648
K3	0,0682	0,1743	0,4335
K4	0,0310	0,0843	0,2177
K5	0,0195	0,0322	0,0773

Table 34: Probability degree matrix

	K1	K2	K3	K4	K5	Minimum	Weight
K1	-	1	1	1	1	1	0,36
K2	0,80	-	1	1	1	0,80	0,29
K3	0,34	0,72	-	1	1	0,34	0,12
K4	0,80	0,62	0,62	-	1	0,62	0,23
K5	0	0	0,02	0,47	-	0	0

As seen in the matrix, the weight value for criterion K5 (time) is set as 0.

The disadvantage of this model is that it cannot assign weight values to some criteria in the problem. This is not an acceptable situation, because in this case some values must be ignored when making a choice. (ENEA, 2004)

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4.5.2 Comparison of the Sub-Criteria of the Main Criterion of Practicability

The criteria weights of the technical competence, capacity, outsourcing sub-criteria determined based on the main criteria of applicability are as follows

K1: Technical competence
K2: Capacity
K3: Outsourcing

Table 35: Decision matrix created with triangular fuzzy numbers

	K1	K2	K3
K1	(1,1,1)	(1,3,5)	(5,7,9)
K2	(1/5,1/3,1)	(1,1,1)	(3,5,7)
K3	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1,1,1)

Table 36: Fuzzy synthetic(S) decision matrix

	l	m	u
K1	0,2742	0,589	1,2044
K2	0,1645	0,3391	0,7227
K3	0,0491	0,0719	0,1231

Table 37: Probability degree matrix

	K1	K2	K3	Minimum	Weight
K1	-	1	1	1	0,61
K2	0,64	-	1	0,64	0,39
K3	0	0	-	0	0

As seen in the matrix, the weight value for criterion K3 (outsourcing) is set as 0.

4.5.3 Formation of comparative matrices of sub-criteria of the main profit criterion

The criteria weights of the R&D cost, production cost and sales price sub-criteria, which are determined based on the main profit criteria, are as follows.

K1: R&D cost
K2: Production cost
K3: Product Selling price

Table 38: Decision matrix created with triangular fuzzy numbers

	K1	K2	K3
K1	(1,1,1)	(1,3,5)	(5,7,9)
K2	(1/5,1/3,1)	(1,1,1)	(3,5,7)
K3	(1/9,1/7,1/5)	(1/7,1/5,1/3)	(1,1,1)

Table 39: Fuzzy synthetic(S) decision matrix

	l	m	u
K1	0,2742	0,589	1,2044
K2	0,1645	0,3391	0,7227
K3	0,0491	0,0719	0,1231

Table 40: Probability degree matrix

	K1	K2	K3	Minimum	Weight
K1	-	1	1	1	0,61
K2	0,64	-	1	0,64	0,39
K3	0	0	-	0	0

As can be seen in the matrix, the weight value for criterion K3 (selling price) is set as 0.

The weight values of the main and sub-criteria were determined, and then the weight values of the main criteria were multiplied by the calculated weight values of the sub-criteria to obtain a common global weight value and the study proceeded based on these weight values. (Peker, 2014)

Table 41: Main Criteria and sub-criteria are listed according to the BAHP method

Main Critera	Local Weight	Sub-main Criteria	Local Weigh t	Overall Weight
Market share	0,36	-	-	0,3618
Profit	0,29	R&D Cost	0,6089	0,1759
		Product Cost	-	-
		Product Selling Price	0,3911	0,1129
Pacticabilit y	0,12	Technical Competenc e	0,6089	0,0752
		Capacity	0,3911	0,0483
		Outsourcin g	-	-
Budget	0,23	-	-	0,2259
Date	-	Project Time	-	-
		Payback Period	-	-

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Table 42: Criteria weights are ranked in descending order

Criteria		Weight
x1	Market share	0,3618
x2	R&D Cost	0,1759
x3	Product Cost	-
x4	Technical Competence	0,0752
x5	Budget	0,2259
x6	Capacity	0,0483
x7	Product Selling Price	0,1129
x8	Project Time	-
x9	Outsourcing	-
x10	Payback Period	-

4.6 Fuzzy TOPSIS Progressive

Using the weights determined with Fuzzy AHP, project selection / ranking was made with Fuzzy TOPSIS, which is mentioned as a widely used method in the literature.

Table 43: Fuzzy Decision matrix

	x1 +			x2 -			x3 -			x4 +			x5 -		
a1	7	9	10	7	9	10	7	9	10	3	5	7	7	9	10
a2	3	5	7	1	3	5	3	5	7	3	5	7	5	7	9
a3	1	3	5	3	5	7	3	5	7	5	7	9	3	5	7
a4	1	3	5	3	5	7	3	5	7	3	5	7	1	3	5
a5	3	5	7	5	7	9	9	10	10	5	7	9	1	3	5
cj+	10									9					
aj-				1			3						1		

Table 44: Fuzzy Decision matrix more

	x6 +			x7 +			x8 -			x9 -			x10 -		
a1	3	5	7	7	9	10	7	9	10	1	3	5	7	9	10
a2	3	5	7	7	9	10	9	10	10	1	3	5	3	5	7
a3	7	9	10	5	7	9	7	9	10	0	1	3	3	5	7
a4	3	5	7	3	5	7	7	9	10	1	3	5	3	5	7
a5	5	7	9	7	9	10	7	9	10	1	3	5	7	9	10
cj+	10			10											
aj-							7			0			3		

Table 45: Normalized fuzzy decision matrix

	x1 +			x2 -			x3 -			x4 +			x5 -		
a1	1	0,9	0,7	10	9	7	3,33	3	2,33	0,78	0,56	0,33	10	9	7
a2	0,7	0,5	0,3	5	3	1	2,33	1,67	1	0,78	0,56	0,33	9	7	5
a3	0,5	0,3	0,1	7	5	3	2,33	1,67	1	1	0,78	0,56	7	5	3
a4	0,5	0,3	0,1	7	5	3	2,33	1,67	1	0,78	0,56	0,33	5	3	1
a5	0,7	0,5	0,3	9	7	5	3,33	3,33	3	1	0,78	0,56	5	3	1

Table 46: Normalized fuzzy decision matrix more

	x6 +			x7 +			x8 -			x9 -			x10 -		
a1	0,7	0,5	0,3	1	0,9	0,7	1,43	1,29	1	0	0	0	3,3	3	2,33
a2	0,7	0,5	0,3	1	0,9	0,7	1,43	1,43	1,29	0	0	0	2,3	1,67	1
a3	1	0,9	0,7	0,9	0,7	0,5	1,43	1,29	1	0	0	0	2,3	1,67	1
a4	0,7	0,5	0,3	0,7	0,5	0,3	1,43	1,29	1	0	0	0	2,3	1,67	1
a5	0,9	0,7	0,5	1	0,9	0,7	1,43	1,29	1	0	0	0	3,3	3	2,33

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Table 47: Weighted normalized decision matrix

	x1 +			x2 -			x3 -			x4 +			x5 -		
w	0,3618			0,1759			0			0,0752			0,2259		
a1	0,36	0,33	0,25	1,8	1,58	1,23	0	0	0	0,06	0,04	0,03	2,26	2,03	1,58
a2	0,25	0,18	0,11	0,9	0,53	0,18	0	0	0	0,06	0,04	0,03	2,03	1,58	1,13
a3	0,18	0,11	0,04	1,2	0,88	0,53	0	0	0	0,08	0,06	0,04	1,58	1,13	0,68
a4	0,18	0,11	0,04	1,2	0,88	0,53	0	0	0	0,06	0,04	0,03	1,13	0,68	0,23
a5	0,25	0,18	0,11	1,6	1,23	0,88	0	0	0	0,08	0,06	0,04	1,13	0,68	0,23
A+	0,2533			1,2311			0			0,0418			1,5814		
A-	0,1809			0,8793			0			0,0585			1,1296		

Table 48: Weighted normalized decision matrix more

	x6 +			x7 +			x8 -			x9 -			x10 -		
w	0,0483			0,1129			0			0			0		
a1	0	0,02	0,01	0,1	0,1	0,08	0	0	0	0	0	0	0	0	0
a2	0	0,02	0,01	0,1	0,1	0,08	0	0	0	0	0	0	0	0	0
a3	0,1	0,04	0,03	0,1	0,08	0,06	0	0	0	0	0	0	0	0	0
a4	0	0,02	0,01	0,1	0,06	0,03	0	0	0	0	0	0	0	0	0
a5	0	0,03	0,02	0,1	0,1	0,08	0	0	0	0	0	0	0	0	0
A+	0,0338			0,0791			0			0			0		
A-	0,0338			0,0791			0			0			0		

Table 49: Distance of alternatives from the fuzzy positive optimum solution and the fuzzy negative optimum solution

	d+	d-
a1	0,9613	1,7538
a2	1,2718	1,1540
a3	1,2438	0,7917
a4	1,6418	1,0271
a5	1,4097	1,1415

Table 50: Ranking based on proximity coefficient

	C_j	Normalized
a1	0,6459	0,2757
a2	0,4757	0,2031
a3	0,3889	0,1660
a4	0,3849	0,1643
a5	0,4475	0,1910

As seen in Table 51, according to the Fuzzy TOPSIS method, the project selection ranking was determined as a1 > a2 > a5 > a3 > a4 and Project 1 was selected as the most appropriate project to invest in.

V. CONCLUSION

In this study, it is aimed to select the most optimum project for the company to invest in a leading company in the FMCG sector based on the project selection problem with 5 main criteria, 8 sub-criteria and 5 alternatives.

In problem solving, AHP, which is the most commonly used method in the literature for weighting the criteria, and TOPSIS, VIKOR, which are the most commonly used methods in project selection in the literature, and ARAS method, which is rarely used, were used to address the project selection problem. Since ARAS method studies are scarce in the literature, it is aimed to fill this gap in the literature. In order to minimize or even eliminate the uncertainty in decision making methods, the study is supported by Fuzzy AHP and Fuzzy TOPSIS methods. In the study, it was determined that the ARAS method, which is rarely used in the literature, works in harmony with the widely used AHP, TOPSIS and VIKOR methods.

Table 51. Project Selection Application Data.

MCDM Method	Selected Project
Fuzzy TOPSIS	1
TOPSIS	1
VIKOR	1
ARAS	1

It has been observed that all the CRM techniques used in the study selected project 1 as the most optimum project for the company.

Table 52: Project Ranking Application Data

MCDM Method	Project Ranking
TOPSİS	a1>a2>a5>a3>a4
ARAS	a1>a2>a3>a5>a4
VIKOR	a1>a2>a5>a3>a4
FUZZY TOPSİS	a1>a2>a5>a3>a4

It has been observed that TOPSIS, Fuzzy TOPSIS and VIKOR methods, which are among the CRM methods used in the study, are fully compatible with each other and give the same results in project ranking. However, there is a difference in the ARAS method in the 3rd and 4th ranked project. It is thought that the different result of this ARAS method lies in the relative similarity of each alternative to the ideal alternative of the method algorithm, unlike other methods. For example, let's say the optimal value of the criterion is 10, but the highest score is 9 when evaluating the alternatives according to this criterion; the optimal value of the criterion is 1.0 in other CRM methods, while in the ARAS method, it is 0.9. (ECER, 2016)
With this study;

It is suggested that these mathematical methods can be used to simplify decision making and make the right decision in situations involving many factors and alternatives.

This application in the FMCG sector, where project selection decisions and many decision problems are frequently encountered, has brought a scientific approach to investment project selection problems.

It has contributed to the literature with the use of AHP, BAHP in project criteria weighting; TOPSIS, Bulank TOPSIS, VIKOR and ARAS methods in project selection, and it has been proven that the methods work in harmony with each other. It is predicted that these mathematical models can be used in different decision making problems of the company.

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