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RANKING OECD COUNTRIES WITH MULTI CRITERIA DECISION MAKING APPROACH BY USING RESEARCH AND DEVELOPMENT

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(Indicators, This study is derived **thesis** from "Ranking OECD Countries With Multi Criteria Decision Making Approach By Using Research and Development Indicators**".)**

ABSTRACT

Research and Development (R & D) is one of the most critical areas in which both institutions and countries are concerned. Through its indicators, countries can measure the extent of their progress and development, in addation to know which areas need more attention at present and in the future.Organization for Economic Co-operation and Development (OECD) countries consider as the most developed, economicl development and interest in research and development as a basic field to demonstrate the progress and raise it among other countries. The research aims to find the ranking of these countries according research and development (R & D) indicators (4 indicarors) and determine Turkey's position among them by using some of Multi-Criteria Decision Making (MCDM) techniques which are MAUT, AHP, and TOPSIS, in addition to check the potentional correlation between this ranking and IDI, HDI as a global indexse. The results shown that Korea and Japan were in the top three places at the ranking, Turky's position came late in the ranking, and approve that there is a sufficient positive correlation between the OECD countries ranking by R & D indicators and both of HDI and IDI and it shown also MAUT method is the strongest technique that describe the correlation better than other methods.

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KEYWORDS:AHP,HDI, IDI, MAUT, MCDM, OECD, R&D, Ranking, TOPSIS.

1. Introduction

Nations seeks to develop their educational and innovative capacities in order to maintain a continuous economic growth rate. Long-term national investment in research and development (R&D) plays an important role in find and improve innovations through a complex systemthat includes a combined talents of scientists, entrepreneurs, engineers, business managers and industrialists. These things have led everything from nothing to existence, from small initiatives in entrepreneurship world to the great growth in technology industries with millions of workers employed in these industries. All of these advantages are credited in the field of R & D on both private and public sectors (National Science Board, 2012).

It is clear that the R & D factor is the basis upon which the governments of the countries depend. Progress and reach to the higher position depends on it mainly and significantly. Therefore, countries must know their capabilities among similar countries so that they can be carried out in a manner that achieves the well-being of their peoples and prevents them from lagging behind and delaying development processes (Chatziparadeisis, 2006).

Ranking and classification of countries according to R & D components is a problem in our time because of the great acceleration in knowledge related to economic and environmental processes. To resolve this type of issues, we need a strong type of decision making can deal with different sorts of criteria with complex and huge data. Multi Criteria Decision Making emerged to be the most suitable tool for any decision maker to choose appropriate alternative among all available alternatives (De Montis et al., 2004).

There are lots of studies for ranking countries. Eren (2016) listedthe countries have been in terms of sustainability. Özarı, Turan and Demir (2016):Between the years 1992-2014 were evaluated Russian economy via Topsis method.

Organization for Economic and Co-operation Development (OECD) consider as the most of the organizations contain updated data on a variety topics related to the global community. The importance of this organization is that it brings together 39 countries around the world, which make up 80% of the world trade and investment, which means that member countries are the world's highest economy and the most influential negatively or positively on global economic market (OECD, 2017).

From all mentioned above, this research try to find a decent classification of these countries according to their research and development factor and as the most important

economically countries around the world, using some of the appropriate multi criteria decision-making techniques for the ranking process.

2. Research Metodology

The methodology of data extraction will be explained and the steps of various multi criteria decision-making techniques used in this research, which are AHP, TOPSIS and MAUT. In addition to show the OECD data for all R & D indicators and then to check the correlation between the R&D ranking and both IDI , HDI indexes. Figure 1 illustrate the steps of study by a visual model.

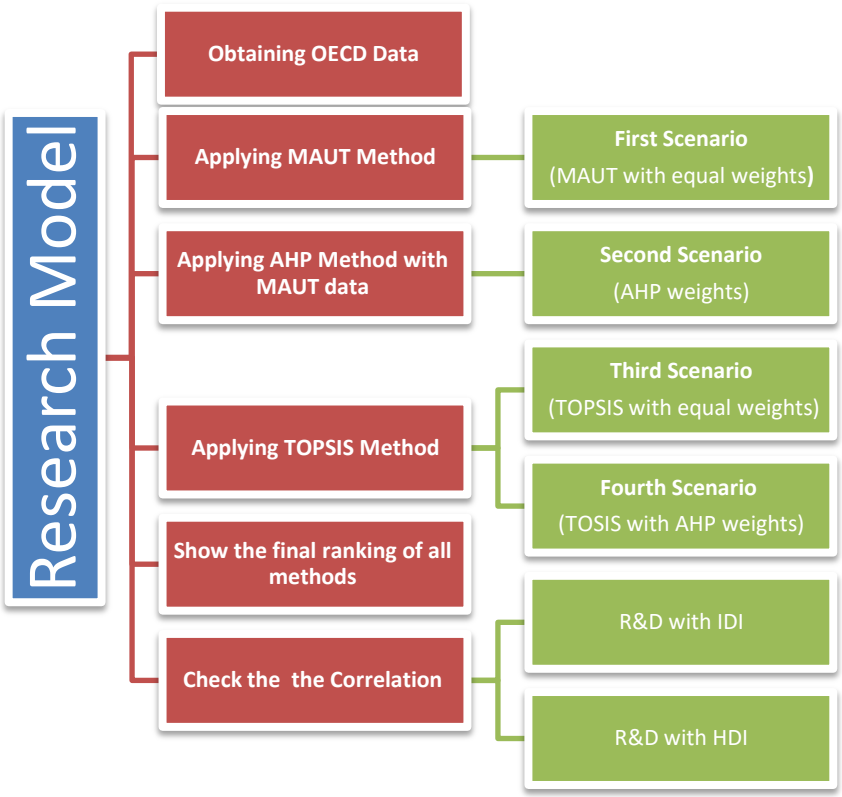

Figure 1: Research Model

2.1 Research Data and Scenarios

1. Indicators measurement units:
    a. GDP= PC_GPD (Per Capita Gross Domestic Product)
    b. Researchers= 1000EMPLOYED (per 1 000 people employed and in number of researchers; the data are available as an overall and divided by gender)
    c. Government Researchers= PC_NATIONAL (percentage of national total)
    d. Triadic patent families = NBR (number)
2. Four assumptions (scenarios) will be used to rank OECD countries by using MCDM techniques:

a. **First Scenario:**Assume all indicators has the same weight (25%), MAUT method will be used in this scenario.
b. **Second Scenario:**Assume that there are different weights for each indicator, MAUT by AHP weights methods will be used
c. **Third Scenario:**TOPSIS method with initial data, same weights (%25) for each indicator (criteria).
d. **Fourth Scenario:**TOPSIS by using AHP weights matrix.

3. For correlation, take the same countries of OECD from HDI and IDI indexes not the whole indexes.

2.2Multi Attribute Utility Theory (MAUT)

The origins of MAUT were set by Churchman, Ackoff and Arnoff (1957) who start addressed a multiple criteria decision problem using a simple additive weighting method. For using MAUT method, and after obtaining OECD data, MAUT method steps were applied and use the initial OECD R & D indicators data as the first scenario, as follow:

1. Construct the decision matrix which contains the same initial OECD data which obtained previously.
2. Determine which indicator (criteria) must be maximized and which one must be minimized.
    a. In our case, all of the indicators (criteria) must be maximized, because we are looking for the heights utility for the countries.
    b. Extract the Max. value for each indicator (criteria) by using max() function.

Table 1: Max Indicators Values

Max GDP	Max Researchers	Max Gov. Rec.	Max Patent
4.231985578	15.02194282	48.02864609	17121.41
KOR	FIN	ARG	JPN

c. Extract the Min. value for each indicator (criteria) by using min() function.

Table 2: Min Indicators Values

Min GDP	Min Researchers	Min Gov. Rec.	Min Patent
0.385629422	0.606955634	2.302960752	1.8145

CHL	MEX	IRL	ISL

3. Calculate the normalized utility (values) as follow:

   For maximized:

$$u(x) = \frac{x - x^-}{x_i^+ - x_i^-} \quad \textbf{(1)}$$

   For minimized:

$$u(x) = \frac{x_i^+ - x}{x_i^+ - x_i^-} \quad \textbf{(2)}$$

Where: x = value of country indicator (criteria)

x_i^+= The maximum value among values

x_i^-= The minimum value among values

In our case we will use the first formula for normalized values, because as it mentioned before, all of our criteria is maximized.

4. After applying the third (3) step on all alternatives (countries), get the total utility for each alternative by using sum() function for four (4) R & D indicators.

2.3 Analytical Hierarchy Process (AHP)

It is a common type of Multi Criteria Decision Making techniques that presented originally by Thomas Satty (1980), and it used when the decision maker dealing with complex decision making. For applying this method we assume that scenario the input data will be taken from MAUT method not the initial data of OECD, and it goes as follow:

1. Develop the weights for criteria:

   And for applying this step, we used pairwise comparison matrix which explained in literature before with the equation:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad \textbf{(3)}$$

Where:

$$a_{ji} = 1\ a_{ji} = \frac{1}{a_{ij}} \qquad a_{ji} \neq 0 \tag{4}$$

Table 3: Comparision Matrix.

R&D Indicators	Patent	GDP	Researchers	Gov. Researchers
Patent	1.00	3.00	5.00	7.00
GDP	1/3	1.00	3.00	1.00
Researchers	1/5	1/3	1.00	2.00
Gov. Researchers	1/7	1.00	1/2	1.00

2. Get the weights from the first step (1) by calculating the summation of pairwise comparison values and put it for each indicator (criteria), and in our case we assume the priority for indicators relevant importance as follow:
    a. Most important indicator: Patent
    b. Second important indicator: GDP
    c. Third important indicator: Researchers
    d. Last and less important indicator : Government Researchers.

Table 4: Calculate Relative Importance

Indicators	Patent	GDP	Researchers	Gov. Researchers
Patent	0.60	0.56	0.53	0.64
GDP	0.20	0.19	0.32	0.09
Researchers	0.12	0.06	0.11	0.18
Gov. Researchers	0.09	0.19	0.05	0.09

And to get the wieghts, take Average for the indicators values horizanally:

Table 5: Indicators Weights.

Indicators	Weights
Patent	0.58
GDP	0.20
Researchers	0.12
Gov. Researchers	0.10

3. Multiply the indicator weight with each alternative value, and get the total utility by summation of all indicators values for each indicators.

2.4 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS):

It is other type of Multi Criteria Decision Making methods which originally provided by Hwang and Yoon (1981) and it assists the decision makers have to select the best alternative that should be the closest and the shortest distance to the positive ideal solution and farthest from negative ideal solution.For applying this method, we assume two different scenarios:

1. Applying TOPSIS with equal weights for each indicator.
2. Applying TOPSIS with AHP weights.

- **Applying TOPSIS with equal weights**

To apply this scenario, we go with these steps:

1. Construct the decision matrix and determine the weight of criteria.
    a. Decision matrix will take the initial OECD data as input data.
    b. The weights for each indicator (criteria) is %25. Total weights is %100 and we have 4 indicators, so %100/4 = %25 for each one.
2. Calculate the normalized decision matrix.
    a. For this step, we can apply the following equation:

$$r_{ij} = f_{ij} \Big/ \sqrt{\sum_{J=1}^{J} {f_{ij}}^2} \qquad \textbf{(5)}$$

$$j = 1, \dots, J; \quad i = 1, \dots, n.$$

    b. To make it easier, firstly we take the Square for each alternative value for each indicator.
    c. Then take the summation of all alternatives values for each indicator that comes from step (b) by sum() function.
    d. After that take the square root for the summation valuesfrom step c by SQRT() function.
    e. Finally, apply the equation by divide the initial value for each alternative for each indicator by the final value for each indicator which comes from step (d).

3. Calculate the weighted normalized decision matrix by multiplying each value with the weight for each indicator which is equal %25 for all indicators as determined before by this equation:

$$vij = wirij$$

$$j = 1, \dots, J; \quad i = 1, \dots, n.$$

$$\text{Vij}=\begin{bmatrix} w_i r_{11} & w_i r_{12} & \cdots & w_n r_{1n} \\ w_i r_{21} & w_i r_{22} & \cdots & w_n r_{2n} \\ \vdots & \vdots & & \vdots \\ w_1 r_{n1} & w_2 r_{n2} & \cdots & w_n r_{nn} \end{bmatrix} \quad \textbf{(6)}$$

4. Determine the positive ideal and negative ideal solutions and for this step we have:
   a. To get the positive ideal solution A^+, we will apply the following equation:

$$A^+ = (v_1^+, v_2^+, \cdots, v_n^+) = \left\{ \left(\max_i \{v_{ij}\}\, j \in B\right), \left(\min_i \{v_{ij}\}\, j \in C\right) \right\} \quad \textbf{(7)}$$

   b. To get the negative ideal solution A^-, we will apply the following equation:

$$A^- = (v_1^-, v_2^-, \cdots, v_n^-) = \left\{ \left(\max_i \{v_{ij}\}\, j \in B\right), \left(\min_i \{v_{ij}\}\, j \in C\right) \right\} \quad \textbf{(8)}$$

   c. Use Max() function for all values for each indicator to get maximum value, and use Min() function for all values for each indicator to get minimum value
5. Calculate the distance measures from the positive ideal solution and the negative ideal solution by these steps:
   a. Distance from Positive ideal solution S_i^+ by use the following equation:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - V_j^+\right) 2}\ i = 1, \dots, n. \quad \textbf{(9)}$$

   b. Distance from Negative ideal solution S_i^- by use the following equation:

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - V_j^-\right) 2}\ i = 1, \dots, n. \quad \textbf{(10)}$$

   c. And for measure distance from the Positive and Negative solutions, take the square root by SQRT() function for the summation the Square (power 2) of subtracting the each alternative value for each indicator from Positive ideal solution $A^+$from distance from Positive ideal solution S_i^+, and the same values

but subtracting from Negative ideal solution $A^-$for distance for obtain the distance from Negative ideal solution S_i^-.

6. Calculate the relevant closeness to positive ideal solution C_i^+ by apply the following equation:

$$C_i^+ = \frac{S_i^-}{S_i^- + S_i^+} i = 1, \dots, n. \qquad \textbf{(11)}$$

   a. For this step we have to take distance from Negative ideal solution S_i^- value for each alternative and divide it by the summing of distance from Negative ideal solution S_i^- value and distance from Positive ideal solution S_i^+.
   b. Finally rank the preference order or select the alternative which is the most closest to 1 depending on step (a).

- **Applying TOPSIS with AHP weights.**

To apply this scenario, we go with the same steps for the third scenario, but the different will be started from the third step as follow :

3. Calculate the weighted normalized decision matrix by multiplying each value with the weight for each indicator by equation **(6).**
   a. In this scenario we will take the AHP weights by using pairwise comparison which applied in AHP method, and the indicators importance preference will be as follow:

      1- Most important indicator: Patent
      2- Second important indicator: GDP
      3- Third important indicator: Researchers
      4- Last and less important indicator : Government Researchers

   b. After this step, we will go with the same remain steps of third scenario, but the values of Positive and Negative ideal solutions and the distances from for each indicator Positive and Negative ideal solutions will differ depending on new weights (AHP weights).

2.5 Checking the Correlation:

This part test the correlation between the final R & D ranking for OECD countries with bothICT Developmet Index (IDI) and Human Development Index (HDI) by using the final OECD countriers ranking of R&D indicators by MAUT and TOPSIS methods (first and third scenarios).

a. Correlation with ICT Developmet Index (IDI):

IDI is an international index and to reflect the improvements that occur in countries at various ICT development fields (ITU 2016). As it mentioned before, we got the ICT Development Index (IDI) for 2016, and just take the same countries of OECD countries to check out the correlation value between *ICT Development Index (IDI)* and *Ranking OECD countries with MAUT method by R&D indicators* which it is:

Table 6: Correlation between MAUT R&D Ranking and IDI.

Tested Correlation	Correlation Value
MAUT R&D Rank and IDI	0.697773893

The correlation value between *ICT Development Index (IDI)* and *Ranking OECD countries with TOPSIS method by R&D indicators* which it is:

Table 7: Correlation between TOPSIS R&D Ranking and IDI

Tested Correlation	Correlation Value
TOPSIS R&D Rank and IDI	0.38800124

b. Correlation withHuman Development Index (HDI)

HDI is a new portal describing life and human renaissance so that it cares about human life, their specialties and their different and varied interests according to the environment of their societies (UNDP 2016).As it mentioned before, we got the Human Development Index (HDI) for 2016, and just take the same countries of OECD countres to check out the correlationvalue between *Human Development Index (HDI)* and *Ranking OECD countries with MAUT method by R&D indicators* which is:

Table 8: Correlation between MAUT R&D Ranking and HDI

Tested Correlation	Correlation Value
MAUT R&D Rank and HDI	0.589695193

The correlation value between *Human Development Index (HDI)* and *Ranking OECD countries with TOPSIS method by R&D indicators* which it is:

Table 9: Correlation between TOPSIS R&D Ranking and HDI

Tested Correlation	Correlation Value
TOPSIS R&D Rank and HDI	0.300975254

3. Conclusion and Future Studies

In this study, MAUT, AHP, and TOPSIS methods were used to rank OECD countries by R&D indicators which are GDP Spending on R&D, Researchers, Government Researchers and Triadic patent families.These methods were used by put some assumptions (scenarios) for each of them, the first scenario was ranking OECD countries depending on R&D indicators by MAUT technique with equal weights, second one was ranking by MAUT also but using AHP weights, third one was ranking by TOPSIS technique with equal weights, while the fourth scenario was ranking the countries by TOPSIS technique with AHP weights. The study find that, in all scenarios, Japan and Republic of Korea were in the top three (3) places at the ranking, and Turkey's opsition was come in the last of the ranking, also it is approve a good positive relation between this ranking and both IDI and HDI as other development indexes, which means this areas are so important to concern about in order to make a good developments and MAUT method has better correlation value than TOPSIS method. And for future researches, there is a possibility to use another MCDM methods to make a ranking, also may use another fields indicators to make the ranking depending on it with different data values.

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