Trakya Üniversitesi Sosyal Bilimler Dergisi
Aralık 2013 Cilt 15 Sayı 2 (111-130)

VISUAL ANALYSIS FOR MULTI CRITERIA DECISION PROBLEMS BY PROMETHEE METHOD AND GAIA PLANE: AN APPLICATION, DETERMINE THE LEVEL OF REGIONAL SOCIO-ECONOMIC DEVELOPMENT IN TURKEY

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ABSTRACT

In this study, it is aimed to show the consistency of the results of PROMETHEE and GAIA Plane, one of the Multi Criteria Decision Making Methods and the applicability of these methods in the field of socio-economic development. For these purposes, it is realized to determine the level of socio-economic development and to outrank the regions according to selected socio-economic criteria. In this study 7 geographic regions are included.

Keywords: *Multi Criteria Decision Making, PROMETHEE Methods, GAIA Plane.*

ÇOK KRİTERLİ KARAR VERME PROBLEMLERİ İÇİN PROMETHEE YÖNTEMİ VE GAIA DÜZLEMİYLE GÖRSEL ANALİZLER: TÜRKİYE'DE BÖLGESEL SOSYO-EKONOMİK GELİŞMİŞLİK DÜZEYLERİNİN BELİRLENMESİ ÜZERİNE BİR UYGULAMA

ÖZET

Bu çalışmada, Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden olan ve çeşitli alanlara uygulanan PROMETHEE yöntemi ve GAIA düzleminin tanıtılması, uygulanabilirliği ile bu yöntemle elde edilen sonuçların tutarlılığının gösterilmesi hedeflenmektedir. Bu hedef doğrultusunda sosyal ve ekonomik alanlardan seçilen değişkenler baz alınarak, bölgelerin sosyo-ekonomik gelişmişlik düzeylerinin belirlenmesi ve bu belirleme doğrultusunda sıralama işlemleri gerçekleştirilmiştir.

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Bu amaçlar doğrultusunda gerçekleştirilen çalışma mevcut idari yapı çerçevesinde 7 coğrafi bölgeyi kapsamaktadır.

Anahtar Kelimeler: *Çok Kriterli Karar Verme, PROMETHEE Yöntemi, GAIA Düzlemi.*

1. INTRODUCTION

Most of the economical, industrial, financial or political decision problems are multicriteria. Nobody buys a car on base of the price only (financial criterion); the comfort, the quality, the performance, the prestige, … is obviously always taken into account. On the other hand nobody reacts in the same way. Indeed one can observe many different cars in the streets. The election is submitted to each individual's personal taste. Everybody allocates a different set of weights to the criteria. The problem of the selection or the ranking of alternatives submitted to a multicriteria evaluation is not an easy problem. Neither economically nor mathematically! Usually there is no optimal solution; no alternative is the best one on each criterion. A better quality implies a higher price. The criteria are conflicting. Compromise solutions have to be considered. Why not the best compromises?(Brans and Mareschal, 2012)

The development of Multi Criteria Decision Making (MCDM) methods has been motivated not only by a variety of real-life problems requiring the consideration of multiple criteria, but also by practitioners' desire to propose enhanced decision making techniques using recent advancements in mathematical optimization, scientific computing, and computer technology. The impact that the MCDM paradigm makes on business, engineering, and science is being reflected in the large number of articles with MCDM-type studies and analyses which are presented at professional meetings in various disciplines (Wiecek et al, 2008).

Multi-criteria approaches have been developed basically in two schools, the European Multi-criteria Decision Aid (MCDA) and the American Multi-criteria Decision Making (MCDM). The former differs from the latter in that it seeks to give recommendations, whereas the American MCDM school tries to approach an ideal solution, derived from a set of axioms (Roy, 1996).

The European school preferred to investigate discrete methods and outranking relations (an aggregation of options to derive a ranking depends upon pairwise comparisons of the options and upon evaluating to what degree one option is better or worse than another based on the different

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criteria employed). The Americans supported additive utility methods (they use a certain form of utility or value function as a basis for aggregation). In the 1980s, interactive computer methods were introduced, which greatly facilitate the communication with decision makers. By 1985, multi-criteria methods had attained a world-wide reputation and are now promoted by different societies (Hatefi and Torabi, 2010).

Many MCDA methods have been proposed. All these methods start from the same evaluation table, but they vary according to the additional information they request. The PROMETHEE methods require very clear additional information, that is easily obtained and understood by both decision-makers (DM) and analysts (Brans and Mareschal, 2005).

2. PROMETHEE METHOD

The PROMETHEE method (**P**reference **R**anking **O**rganization **Meth**od for **E**nrichment **E**valuations) is one of the most recent MCDA methods that was developed by Brans (1982) and further extended by Brans and Vincke (1985). PROMETHEE methods' main features are simplicity, clearness and stability. The notion of generalized criterion is used to construct a valued outranking relation. All the parameters to be defined have an economic signification, so that the DM can easily fix them. With PROMETHE, it is possible to obtain either a partial preorder (PROMETHEE I) or a complete one (PROMETHEE II), both on a finite set of feasible actions (Brans, Vincke and Mareschal, 1986).

The main aim of the PROMETHEE approach is to be as easily understood as possible by the DM. It is based on extensions of the notion of criterion. Six possible extensions are considered. These extensions can easily be identified by the DM because the parameters to be defined (at most 2) have an economic significance. A valued outranking graph is constructed by using a preference index (Brans and Vincke, 1985).

The PROMETHEE methods have been introduced to help a DM to outrank partially or completely a set of actions which are evaluated on several criteria. You can find the basic principles and more details of these methods in Brans et al. (1982, 1985, 1986, 2005).

PROMETHEE shows the degree of dominance of one alternative over the other. Predefined six preference functions are applied to all criteria with parameters, indifference and preference thresholds.

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The implementation of PROMETHEE requires two additional types of information, namely:

• information on the relative importance (i.e.,the weights) of the criteria considered;

• information on the decision-makers preference function, which he/she uses when comparing the contribution of the alternatives in terms of each separate criterion.

2.1. The Principles of the PROMETHEE

2.1.1. Generalized Criterion

For each action a $\in$ K, f (a) is an evaluation of this action.

When we compare two actions a, b $\in$ K, we must be able to express the result of this comparison in terms of preference. We therefore consider a preference function P:

$P: K \times K \longrightarrow$ (0,1)

representing the intensity of preference of action a with regard to action b and such that,

- $P(a,b) = 0$, means an indifference between a and b, or no preference of a over b;
- $P(a,b) \sim 0$, means weak preference of a over b;
- $P(a,b) \sim 1$, means strong preference of a over b;
- $P(a,b) = 1$, means strict preference of a over b.

In practice, this preference function will often be a function of the difference between the two evaluations, so that it can be written;

$P(a,b) = P (f(a) - f(b))$

The graph of such a function is given by Figure 1. It has to be a non-decreasing function, equal to zero for negative values of $d = f(a) - f(b)$.

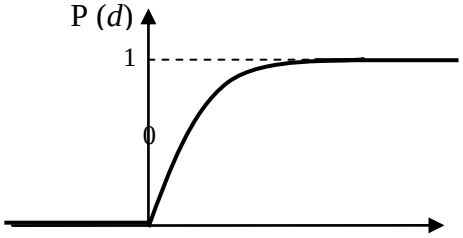

Figure 1: Preference Function P (d)

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For each criterion, f it is considered a generalized criterion defined by f and a corresponding preference function P (Brans, Vincke and Mareschal, 1986).

2.1.2. A Preference Function

A preference function giving the preference of the DM for an action a with regard to b. This function will be defined separately for each criterion; its value will be between 0 and 1. The smaller the function, the greater the indifference of the decision-maker; the closer to 1 the greater his preference.

Let us consider a multicriteria problem as defined in below, each criterion having to be maximized. Let f be a particular criterion and a and b two particular actions of K. The associated preference function $P(a,b)$ of a with regard to b will be defined as (Brans and Vincke, 1985):

$$P(a,b) = \begin{cases} 0 & \text{if } f(a) \leq f(b), \\ p\,[f(a), f(b)] & \text{if } f(a) > f(b), \end{cases} \qquad (2.1)$$

Six type of preference functions were considered to cover all kinds of criteria.

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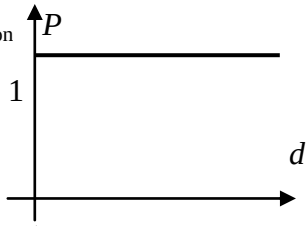
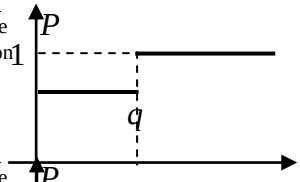
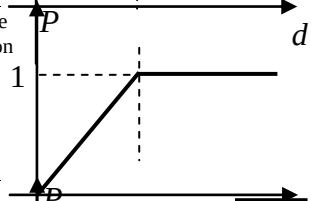
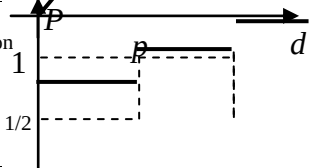
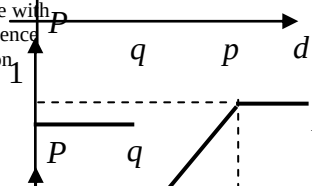
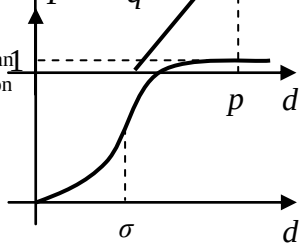
Table 1: Preference Function

Generalised Criterion	Definition	Parameters to fix
Type 1: Usual Criterion 	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 & d > 0 \end{cases}$	-
Type 2: U-shape Criterion 	$P(d) = \begin{cases} 0 & d \le q \\ 1 & d > q \end{cases}$	q
Type 3: V-shape Criterion 	$P(d) = \begin{cases} 0 & d \le 0 \\ d/p & 0 \le d \le p \\ 1 & d > p \end{cases}$	p
Type 4: Level Criterion 	$P(d) = \begin{cases} 0 & d \le q \\ 1/2 & q < d \le p \\ 1 & d > p \end{cases}$	p,q
Type 5: V-shape with indifference Criterion 	$P(d) = \begin{cases} 0 & d \le q \\ d-q/p-q & q < d \le p \\ 1 & d > p \end{cases}$	p,q
Type 6: Gaussian Criterion 	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 - e^{-d^2 / 2\sigma^2} & d > 0 \end{cases}$	σ

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Source: Brans and Vincke, 1985.

There is no path for deciding the preference functions, but below you can see some clues for deciding the preference functions for each criteria. These guidelines will help you to choose the right preference function for your criterion (Mareschal, 2012).

The V-shape (type III) and linear (type V) preference functions are best suited for quantitative criteria (e.g. prices, costs, power, ...). The choice will depend on whether you want to introduce an indifference threshold or not. Actually, V-shape is a special case of the linear one.

The Gaussian (type VI) preference function is less often used as it is more difficult to parameter (the σ threshold value is somewhere between the q indifference threshold and the p preference threshold).

The Usual (type I) and Level (type IV) preference functions are best suited for qualitative criteria. In case of a small number of levels on the criteria scale (e.g. yes/no criteria or up to 5-point scale) and if the different levels are considered quite different from each other, the Usual preference function is the good choice. If you want to differentiate smaller deviations from larger ones, the Level preference function is more adequate.

The U-shape (type II) preference function is a special case of the Level one and is less often used.

In each case 0, 1 or 2 parameters have to be defined, their significance is clear (Brans and Mareschal, 2005):

q is a threshold of indifference;

p is a threshold of strict preference;

σ is an intermediate value between q and p.

The q indifference threshold is the largest deviation which is considered as negligible by the decision maker, while the preference threshold is the smallest deviation which is considered as sufficient to generate a full preference.

When a preference function is chosen, the preference index a over b can be defined for every criteria. The PROMETHEE procedure is based on pairwise comparisons. Let us first define aggregated preference indices and outranking flows.

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$$\begin{cases} \pi(a,b) = \sum_{j=1}^{k} w_j \,.\, P_j(a,b) \\ \pi(b,a) = \sum_{j=1}^{k} w_j \,.\, P_j(b,a) \end{cases} \qquad (2.2)$$

$\pi(a,b)$ is expressing with which degree a is preferred to b over all the criteria and $\pi(b,a)$ how b is preferred to a. In most of the cases there are criteria for which a is better than b and criteria for which b is better than a. Consequently $\pi(a,b)$ and $\pi(b,a)$ are usually positive. The following properties hold for all a,b.

$$\begin{cases} \pi(a,a) = 0, \\ 0 \le \pi(a,b) \le 1, \\ 0 \le \pi(b,a) \le 1, \\ 0 \le \pi(a,b) + \pi(b,a) \le 1, \end{cases} \qquad (2.3)$$

After preference indices determined, we can define the two following outranking flows: (Brans and Vincke, 1985)

- the positive outranking flow:

$$\Phi^{+}(a) = \frac{1}{n-1} \sum_{x \in K} \pi(a, x) \qquad (2.4)$$

- the negative outranking flow:

$$\Phi^{-}(a) = \frac{1}{n-1} \sum_{x \in K} \pi(x, a) \qquad (2.5)$$

Positive outranking flow is an aggregated outranking sum of each alternative over the other alternatives. It shows how it is outranking the other alternatives. Negative outranking flow shows how it is dominated by the other alternatives.

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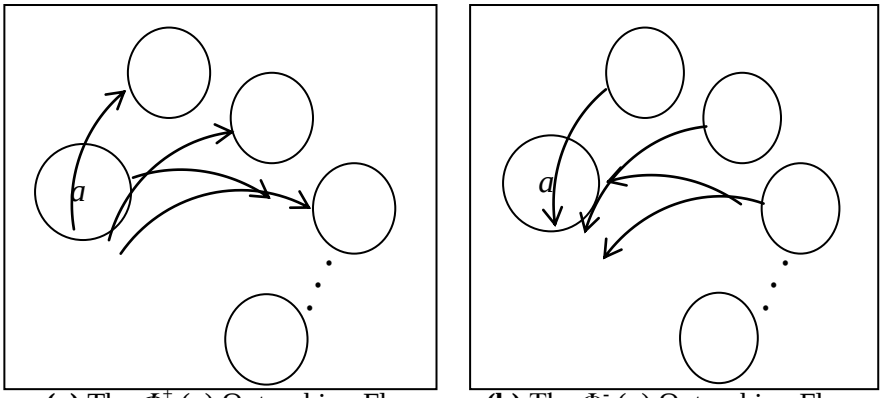

(a) The $\Phi^{+}(a)$ Outranking Flow **(b)** The $\Phi^{-}(a)$ Outranking Flow

Figure 2: The PROMETHEE Outranking Flows
Source: Brans and Vincke, 1985.

2.1.3. PROMETHEE I Partial Ranking

You can find the PROMETHEE I partial ranking from the positive and the negative outranking flows. In order to determine the PROMETHEE I ranking; first define the two total preorders (P^{+}, I^{+}) and (P^{-}, I^{-}) such that: (Brans and Vincke, 1985)

$$a\ P^{+}\ b \quad \text{iff} \quad \Phi^{+}(a) > \Phi^{+}(b),$$
$$a\ P^{-} b \quad \text{iff} \quad \Phi^{-}(a) < \Phi^{+}(b); \tag{2.6}$$

$$a\ I^{+}\ b \quad \text{iff} \quad \Phi^{+}(a) = \Phi^{+}(b),$$
$$a\ I^{-} b \quad \text{iff} \quad \Phi^{-}(a) < \Phi^{+}(b). \tag{2.7}$$

We then obtain the following partial preorder ($P^{(1)}$, $I^{(1)}$, R) by considering their intersection:

$$\begin{cases} a \text{ outranks } b\ (a\ P^{(1)}\ b)\text{: if} & \begin{cases} a\ P^{+}\ b \ \text{ and } \ a\ P^{-} b, \\ a\ P^{+}\ b \ \text{ and } \ a\ P^{-} b, \\ a\ I^{+}\ b \ \text{ and } \ a\ P^{-} b, \end{cases} \\ a \textit{ is indifferent to } b\ (a\ I^{(1)}\ b) : \text{if } \ a\ I^{+}\ b \ \text{ and } \ a\ I^{-} b, \\ a \text{ and } b \textit{ is incomparable } (a\ R\ b) : \text{otherwise} \end{cases} \tag{2.8}$$

The PROMETHEE I partial ranking provides a ranking of alternatives. In some cases, this ranking may be incomplete. This means that some alternatives can not be compared and therefore cannot be included in a complete ranking. This occurs when the first alternative obtains high scores on particular criteria for which the second alternative obtains low scores and the opposite occurs for other criteria. The use of PROMETHEE I then suggests that the DM should engage in additional evaluation efforts. (Macharis et al., 2004)

After PROMETHEE I partial rankings obtained, we can show them in Figure 3 as an example.

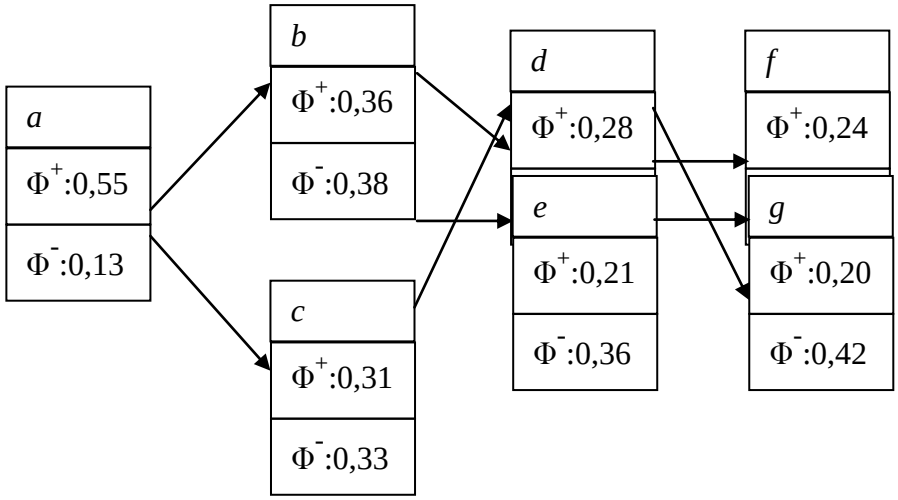

Figure 3: The PROMETHEE I Partial Outranking

You can see that the alternative a outranks all the others. The alternative a seems as the best compromise alternative. It outranks b and c. But b and c are incomparable alternatives with thier positive and negative flows. For this kind of incomparabilities this ranking seems incomplete. To find a complete ranking of the alternatives from the best to the worst one, we will calculate PROMETHEE II results.

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2.1.4. PROMETHEE II Complete Ranking

Suppose a total preorder (complete ranking without incomparabilities) has been requested by the DM. We then can consider for each action $a \in K$ the net-flow. (Brans and Vincke, 1985)

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a) \qquad (2.9)$$

which can easily be used for ranking the actions:

a outranks b ($a\ P^{(2)}\ b$) : iff $\Phi(a) > \Phi(b)$,

a *is indifferent to* b ($a\ I^{(2)}\ b$) : iff $\Phi(a) = \Phi(b)$ (2.10)

This is the PROMETHEE II complete relation. All the actions of ***K*** are now completely ranked.

2.1.5. GAIA Plane

Mareschal and Brans proposed a visual representation tool for PROMETHEE outranking method. (Mareschal and Brans, 1988) This geometrical tool helps the DM both to interactively explore, structure the decision problem and to better understand the results provided by the PROMETHEE outranking method. This is referred to as the GAIA Plane. The underlying idea of this approach is to perform a principal components analysis on the uni-criterion net flows assigned to each action. (De Smet and Lidouh, 2012)

You can see the uni-criterion net flow of the alternative. In the uni-criterion net flow, weights of the criteria are not used.

$$\Phi_j(a) = \frac{1}{n-1} \sum_{b \in A} (P(a,b) - P(b,a)) \qquad (2.11)$$

After calculating the uni-criterion net flow of the alternatives, we can formulate the uni-criterion net flow matrix as below.

	$\Phi_1(.)$	$\Phi_2(.)$	.....	$\Phi_k(.)$
a_1	$\Phi_1(a_1)$	$\Phi_2(a_1)$	.....	$\Phi_k(a_1)$
a_2	$\Phi_1(a_2)$	$\Phi_2(a_2)$	.....	$\Phi_k(a_2)$
.	.	.	.	
.	.	.	.	
.	.	.		.
a_n	$\Phi_1(a_n)$	$\Phi_2(a_n)$	.....	$\Phi_k(a_n)$

Now, we can locate our alternatives in the multidimensional space defined by taking each of those criteria into account (Figure 4).

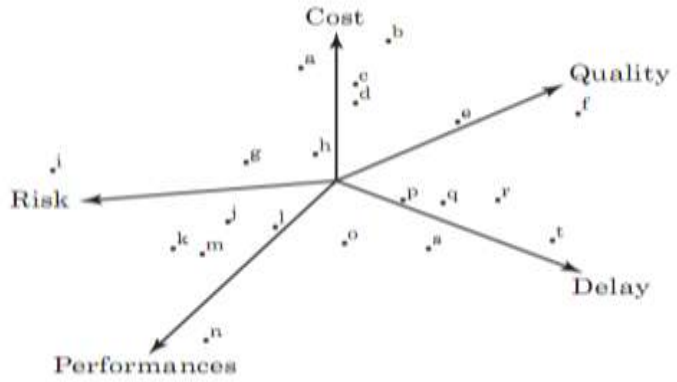

Figure 4: Criteria Space
Source: De Smet and Lidouh, 2012.

When we take set of alternatives and criteria into account, it is often difficult to get a visual representation of it because the numerous criteria will create *k-dimensional* space. We therefore project the alternatives and criteria on a plane. You can see this projection in the Figure 5.

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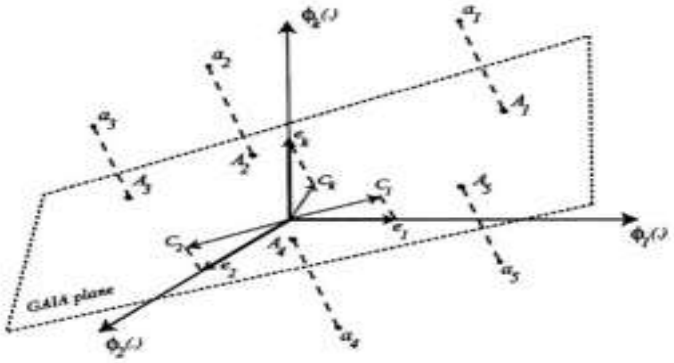

Figure 5: Projection on the GAIA Plane
Source: Mareschal and Brans, 2005.

You can see the criteria and alternatives on two-*dimensional* space known as GAIA Plane. DM use this plane for understanding the results better and deciding easily with visual representation. You can find more information about GAIA Plane in Mareschal and Brans (1988, 2005).

3. APPLICATION

3.1. The Purpose and Scope

Determination of the level of development by means of social, economic and cultural indicators that are measured and compared with each other relatively in the country has been a central issue for the urban planners. Geographic results of economic and social policies which were implemented in the past might be monitored by determining the relative levels. In fact, results of this kind of researches not only reveal the degree of success of existing policies but also provide basis to generate new policies in accordance with the terms of the day.

Nowadays, researchers and international organizations in other countries are conducting researches with different approaches and techniques for socio-economic development patterns for the countries. In these studies, it is emphasized that making a general description of the development is difficult. And all aspects of the definition would be open to debate. In addition, although there is no compromised definition for this, the definitions should be stated in economic, social and cultural areas by using many selected indicators in an integrated approach.

As a result of all these studies, it is accepted that an indication of per capita national income is not a sufficient indicator by itself. With this indicator or similiar indicators, the other economic, social and cultural indicators which may affect the development process should be taken into account.

The main objective of this study includes two main purposes:

4. The criteria chosen on the basis of the social and economic fields can determine the level of socio-economic development and thus enabling a rating to be applied.

5. PROMETHEE method and GAIA plane geometrical representation are used in this study to demonstrate the consistency of the results of the regions which are compared in different criteria of economic, social and cultural indicators.

For the purposes, in this study 7 geographic regions are included.

3.2. The Variables

The variables used in this study are socio-economic indicators which reflect the levels of development across the country for 7 geographic region. These 6 indicators are composed of social and economic variables. To demonstrate the levels of development, sub-categories such as education, health and welfare have been selected.

Educational criteria: Indicators reflect the level of socio-cultural development, "The Literacy Rate" (q1) and "Rate of University Graduates" (q2) are selected for educational criteria. In terms of cause-and-effect relationship, there is a strong link between the level of general education and the level of economic and social development of individuals within a society. One of the most important tools in ensuring the economic and social development, is the education of the required number and quality of manpower.

Health criteria: "Infant Mortality" (q3) which is shown in a thousand and "Doctor" (q4) per ten thousand people are selected for health criteria. Sustain the lives of individuals in terms of health, health care, supply and the potential use of these services, are among the factors that reflect the level of social development. In addition, health care professionals preferences towards to the direction of the advanced regions are directly related to the level of socio-economic development of regions. For these reasons, Doctor per ten thousand people criteria was used in this study as an indicator of

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health. The infant mortality rate is closely related to various socio-economic elements such as the prevalence of health services areas, the high level of education and culture and high economic economic opportunities. Infant mortality rate generally shows the opposite direction with development.

Welfare criteria: "Number of Automobiles" (q5) which is shown in a ten thousand and "Electricity Consumption" (q6) criteria are selected for welfare criteria. Socio-economic development also means the increase in the level of income and wealth.

Improvements in the level of income and wealth, with the possibilities of modern services and utilities benefit from the increased utilization of the mass transmission and communication tools. For that reason Electricity Consumption seems a vital criteria for welfare issues.

In this study, D-Sight software is used for the PROMETHEE method and GAIA Plane. D-Sight has been widely regarded as the main decision software for PROMETHEE method and GAIA Plane. You can reach all the tables, indices and graphical presentations of the PROMETHEE method with D-Sight. D-Sight is more modern software program of PROMETHEE method compared with Decision Lab and previous softwares. D-Sight is a powerful tool for the decision maker, which provides a strong support in the process of solving complex MCDM problems.

3.3. Empirical Results and Overall Evaluation.

In this study, it is aimed to outrank the regions regarding to socio-economic indicators which are described above. You can determine the socio-economic development of the regions with the help of those criteria.

We begin this outranking process with the decision matrix that is shown in Table 2. You can see the alternatives (regions) and criteria (selected indicators) of this study which reflect the levels of development across the country.

Table 2: Decision Matrix for The Regions.

Regions	q_1	q_2	q_3	q_4	q_5	q_6
Marmara	92,40	9,55	39,36	16,43	876	2,19
Ege	89,78	8,42	40,13	14,81	799	1,77
İç Anadolu	90,32	10,31	41,77	17,22	884	1,13
Akdeniz	88,16	8,28	37,13	10,06	615	1,45
Karadeniz	85,82	5,92	42,33	8,73	435	0,99
Güney Doğu Anadolu	73,22	4,99	48,33	5,49	206	0,85
Doğu Anadolu	77,71	6,13	53,36	7,54	197	0,57

Source: http://ekutup.dpt.gov.tr.bolgesel

In PROMETHEE outranking method DM need to decide which preference functions will be used for each criteria. The guideline for deciding the right preference was mentioned in the above. The DM decides the preference functions and parameters regarding to his preferences. DM's preferences for this study are shown in Table 3.

Table 3: Parameters of PROMETHEE

	Comparison	Maximize/ Minimize	Preference Function	Indifference Treshold	Preference Treshold	Weight
K1	Pair Wise	Maximize	V-Shape	--	16	0,167
K2	Pair Wise	Maximize	Linear	2	4	0,167
K3	Pair Wise	Minimize	Linear	1	10	0,167
K4	Pair Wise	Maximize	Level	1	3	0,167
K5	Pair Wise	Maximize	V-Shape	--	172	0,167
K6	Pair Wise	Maximize	V-Shape	--	1	0,167

After setting the parameters, DM obtain the the preference indices by pairwise comparing the alternatives using the equations in (2.2). You can see the preference indices in Table 4. The Preference indices indicate the comparison of alternatives related to all criteria. Indices (π) show how the alternatives are dominating the other alternatives with high values and how the alternatives are weak with low values.

Table 4: The Preference indices(π)

	Marmara	Ege	İç Anadolu	Akdeniz	Karadeniz	Güneydoğu Anadolu	Doğu Anadolu
Marmara	0	0,255	0,214	0,501	0,741	0,981	0,938
Ege	0	0	0,119	0,404	0,568	0,906	0,817
İç Anadolu	0,008	0,171	0	0,358	0,57	0,816	0,891
Akdeniz	0,023	0,037	0,121	0	0,459	0,863	0,685
Karadeniz	0	0	0	0	0	0,581	0,571
Güneydoğu Anadolu	0	0	0	0	0	0	0,13
Doğu Anadolu	0	0	0	0	0	0,13	0

Based on the preference indices, positive, negative and net flow can be calculated with the equations in (2.4), (2.5) and (2.9). Positive outranking flow shows the outranking power of each alternative over the other alternatives. If the Positive outranking flow is high, the outranking power of the alternative is high over the other alternatives. Negative outranking flow shows how it is dominated by the other alternatives. If the negative outranking flow is high, it means that the alternative is weak compared to other alternatives. Net outranking flow shows the final outranking value of each alternative. You can

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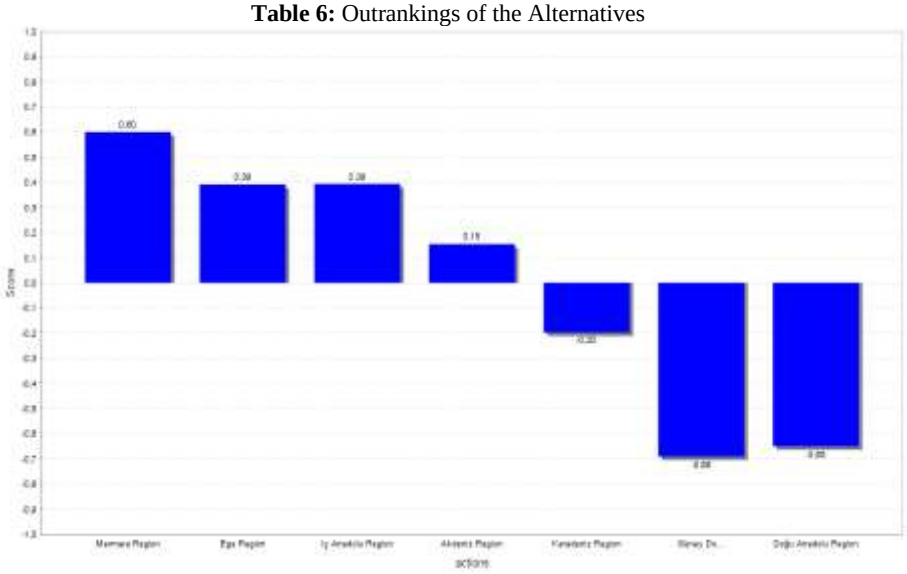
obtain the final ranking of the alternatives with net flows. Table 5 shows the flows and outrankings of the alternatives.

Table 5: The Flows and Outrankings

	Outranking	Net Flow	Positive Flow	Negative Flow
Marmara	1	0,600	0,605	0,005
Ege	3	0,392	0,469	0,077
İç Anadolu	2	0,394	0,469	0,076
Akdeniz	4	0,154	0,365	0,210
Karadeniz	5	-0,198	0,192	0,390
Güneydoğu Anadolu	7	-0,691	0,022	0,713
Doğu Anadolu	6	-0,650	0,022	0,672

You can also determine the outranking of the alternatives in the below. The profiles of the alternatives are shown in the Table 6.

Table 6: Outrankings of the Alternatives



After we got the final ranking with PROMETHEE II results, In the GAIA plane, we should specify that alternatives are represented by points in the plane while the criteria are represented by vectors. You can also distinguish the decision stick with a big dot-vector in red color.

The orientation of the vectors shows which criteria are compatible and which ones are in conflict. You can see on the plane that criteria “Infant Mortality” and “Doctor” are conflicting because they are showing different

directions. But criteria "Rate of university graduates" and "Number of Automobiles" are compatible with each other.

The alternatives which are good at particular criteria situated very close to that particular criteria. Such as İç Anadolu Region is situated very close to the criteria "Doctor". It shows that İç Anadolu Region has high evaluation values in "Doctor" criteria. On the other hand, Güneydoğu Anadolu Region has bad evaluation values in "Doctor" criteria as they are situated in the opposite directions and far from each other.

Groups of alternatives; alternatives which are situated close to each other have similiar profiles. But alternatives with different profiles situated very far from each other. For example, Marmara Region and Güneydoğu Anadolu Region.

In our study, decision stick mainly shows the direction of Marmara Region and Ege Region. It indicates that DM are directed to choose these alternatives for the solution. The alternatives, Karadeniz Region, Doğu Anadolu Region and Güneydoğu Anadolu Region are far from choosing as a best alternatives. That figure is very obvious on the GAIA Plane. GAIA Plane is shown in Figure 6.

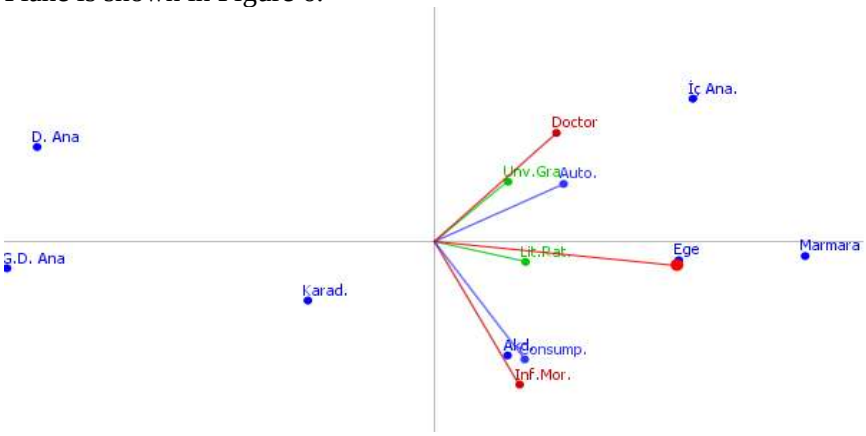


Figure 6: GAIA Plane

Actually we use 6 criteria for the evaluation. We can group our 6 criteria in 3 groups and form the GAIA Plane with this approach. You can see the new formated GAIA Plane in Figure 7. In this GAIA Plane, The Literacy Rate and Rate of University Graduates are grouped under the name of Education. Infant Mortality and Doctor criteria are grouped under the name of Health. Number of Automotive and Electricity Consumption Criteria are grouped under the name of Welfare.

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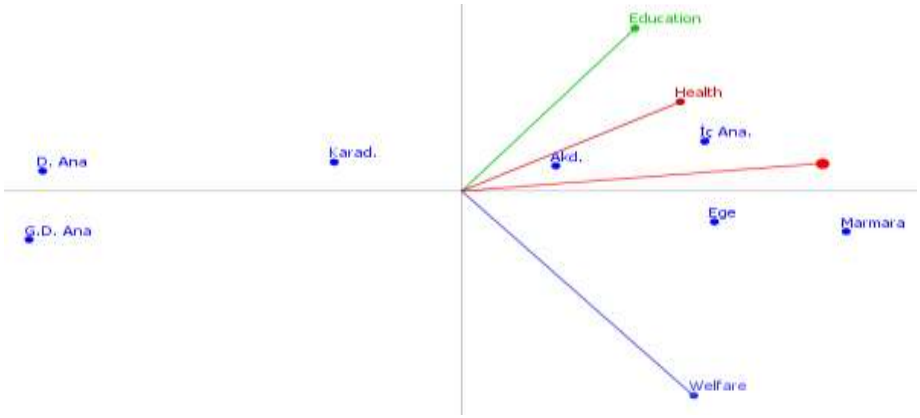

Figure 7: GAIA Plane with New Formulated Criteria

After sorting the criteria in 3 groups, clearer outranking and geometric representation of the criteria can be seen in Figure 7. As in the figure 7, you can see that the alternatives which are good for particular grouped criteria (education, health and welfare) are situated very close to that particular criteria. Such as İç Anadolu Region is situated very close to the grouped criteria "Health". It shows that İç Anadolu Region has high evaluation values in "Health" grouped criteria. On the other hand, Güneydoğu Anadolu Region and Doğu Anadolu Region have bad evaluation values in "Health" criteria as they are situated in the opposite directions from the criteria. You can add these kind of interpretations to this study by examining the Figure 7.

4. CONCLUSION AND GENERAL ASSESSMENT

In this paper, we studied an adaptation of the PROMETHEE Method GAIA Plane in a socio-economic context. We tried to provide a tool to help solve spatial decision problems and proposed PROMETHEE Method and GAIA Plane, a new tool for the visualization of rankings and the information associated them. The paper describes the methods used as well as the modifications that make them usable on socio-economic variables. This work focusses on displaying a maximum of information in a way that will help decision makers have a better understanding of a problem's nature. In the study, we use six socio-economic indicators for analysing the seven geographic regions. As can be seen the results of PROMETHEE application in Table 5, the final ranking is Marmara, İç Anadolu, Ege, Akdeniz, Karadeniz, Doğu Anadolu and Güneydoğu Anadolu. This ranking can be seen as a graphical represantation with GAIA Plane in Figure 6. It can be seen on plane that criteria "Infant Mortality" and "Doctor" are conflicting because they are showing different

directions. But, criteria "Rate of university graduates" and "Number of Automobiles" are compatible with each other. The alternatives which are good at particular criteria situated very close to that particular criteria, such as İç Anadolu region is stuated very close to the criteria "Doctor". It shows that İç Anadolu region has high evaluation values in "Doctor" criteria. On the other hand, Güneydoğu Anadolu Region and Doğu Anadolu Region have bad evaluation values in "Health" criteria as they are situated in the opposite directions from the criteria. You can add these kind of interpretations to this study by examining the Figure 7. As a result, the obtained results are examined in this study, PROMETHEE Method and GAIA Plane give the decision makers very consistent results and provide visual decision making tools.

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