COMPARISON OF TWO DIFFERENT JUDGMENT SCALES WITH THE AHP: GSM OPERATOR PREFERENCE OF UNIVERSITY STUDENTS

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ABSTRACT

The Analytical Hierarchy Process (AHP) is a method with elegant mathematical features that is widely used in multi-criteria decision making. One of the main applications of this method, which is frequently preferred by decision makers due to its systematic and understandable structure, includes addressing inadequacies in terms of numerical scales that are generally used in pairwise comparisons. Therefore, this study includes two different judgment scales, Saaty's fundamental scale and the Balanced scale, which were used in the pairwise comparison stage. After the comparisons were made, the variance related to the consistency ratios and the range of the sensitivity was also observed. In the study, we discuss the use of both judgment scales in a real problem and their effects on priority estimation in the AHP. The study's goal is to evaluate the outcomes of Saaty's fundamental scale and the Balanced scale in the AHP technique for the two current operators in Kosovo's GSM sector, VALA and IPKO, and assess the preference of students in Kosovo. The required data were obtained through a questionnaire and the importance weights of the decision criteria were calculated separately for each scale and compared. The preference order of the GSM operators was discovered according to each decision criterion and all criteria. The ranking of the weights obtained with both scales resulted in IPKO first, followed by VALA. The Balanced scale made the results lighter in the weight distribution. Another important result is that the pairwise comparisons made with the Balanced scale yielded results that are more sensitive. In addition, the closeness of the priority vectors obtained with both scales according to Saaty's compatibility index and Garuti's compatibility index was examined.

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1. Introduction

The mobile phone and GSM sector has some of the fastest technological development. In recent years, there has been a rapid increase in the use of mobile phones in the world. Worldwide, the number of mobile phone subscribers has reached 4.6 billion. While the rate of increase in the number of mobile phone subscribers was 154% in 2004 compared to 2000, it reached 2 billion in 2008 with the increase rate of 15.6% compared to 2004. According to the United Nations Telecommunications Agency, the total number of subscribers using mobile phones is expected to reach 5 billion this year. In 2000, VALA 900 began operations in Kosovo and IPKO began operating in December 2007. VALA 900 PTK-PT is the first GSM operator in Kosovo in this sector. Since the year it was founded, it has developed by increasing its capacity and number of users and offering discounts. From 2000 until 2008, the company held 886,000 subscribers and a 42.19% market share. It reached 1 million users this year and covered 87% of Kosovo's inhabited area.

For mobile phone subscriptions, the market has reached a saturation point. Therefore, GSM operators conduct campaigns aimed at convincing subscribers to switch operators, as well as campaigns aimed at convincing people who are not mobile phone subscribers to become subscribers. Operators with a low market share try to increase their subscriber numbers with attractive marketing campaigns. The operator who is the market leader tries to prevent its subscribers from switching to other operators with marketing campaigns that highlight the advantages of the company which have resulted in their high number of subscribers. It has been observed that mobile phone subscribers change operators due to the communication campaigns offering cheaper options that emerged as a result of this competition. University students constitute a significant portion of GSM operator subscribers. The aim of this study was to determine the order of preference of the GSM operators using the AHP and evaluate these findings. We also aimed to analyze the results comparatively by applying two different scales recommended for the AHP. Saaty's fundamental scale and Salo and Hämäläinen's (1997) Balanced scale were explained and applied to a real problem, and the results were summarized and interpreted. In practice, the students' GSM operator selection was based on the existing GSM operators. Within the framework of this method, we investigated the GSM operator preference of university students in Kosovo.

The main purpose of the application was to compare and interpret the GSM operator ranking with the subjective ranking created using the AHP method, which is used in evaluations that include subjective criteria. In the application, survey data obtained in three languages from the relevant GSM users was used as the data set.

2. Literature review

In the literature, many tools have been used for investment planning in the mobile sector and GSM selection, such as the Analytic Hierarchy Process (AHP), the Analytic Network

Process (ANP), Fuzzy AHP, etc. Some studies used the AHP method to determine the most appropriate GSM operator preference. This section summarizes the literature review focusing on the criteria used in the models.

Table 1
Methods and tools used in investment project evaluation

SUBJECT/PURPOSE	TOOLS/METHODOLOGY	REFERENCE
• To determine consumers' preferences in selecting a mobile network operator	AHP technique	Alhazaymeh, K., Nasruddin H. (2013)
• To determine region evaluation criteria's priority coefficients (RECPC) • To determine country evaluation criteria's priority coefficients (CECPC) • To determine GSM operator evaluation criteria's priority coefficients (GOECPC). • To determine GSM operator's scoring (GOS), ranking and select the best one	AHP technique	Çavuşoğlu, Ö., Canolca, M., and Bayraktar, D. (2010).
• To determine the preferences of university students when buying mobile phone line GSM operators (Turkcell, Vodafone, Avea).	AHP technique	Dündar, S., and Ecer, F. (2008).
• To determine the best mobile value-added service firm providing the most customer satisfaction	Fuzzy synthetic evaluation method AHP	Kuo, Y.F., and Chen, P.C. (2005)
• To analyze the impact of using different judgment scales on the resulting priorities and consistency to default scale as proposed by Saaty	AHP technique	Franek, J., & Kresta, A. (2014)
• To improve the traditional work methods in the selection of fruit	AHP technique	Srđević, Z., & Srđević, B. (2003).

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• To compare different scale functions and derive a recommendation for the application of scales	AHP technique	Goepel, K. D. (2019).
• Proportion judgment scale and introduce a new method based on the proportion scale for construction comparison matrix in the Analytic Hierarchy Process (SHP)	AHP technique	Decai, H., & Liangzhong, S. (2003)
• To determine BEST matching scale according to the mental representation of the verbal scale of each individual decision-maker, verbal scales are first used to compare alternatives with known measures, e.g. surface of figures.	AHP technique with pairwise comparisons	Meesariganda, b. R., & ishizaka, a. (2017).
• To determine the best location for a dry port that would support the container terminals within the hinterland of Kocaeli ports by applying Analytic Hierarchy Process (AHP) with a case study	AHP technique	Saka, M., & Cetin, O. (2020)
• Ranking of the GSM operators	Fuzzy ANP	Erginel, N., & Sentürk, S. (2011).

2.1 Analytic Hierarchy Process – AHP

The Analytic Hierarchy Process (AHP) is a multi-criteria decision structured technique for organizing and analyzing complex decisions. It was developed by Thomas Saaty and has been widely used since 1970. The AHP assists decision makers by enabling the conversion of verbal assessments into numerical values, which allows pairwise comparisons to rank the choices in order of importance. Therefore, the AHP is a very helpful way to make a choice when there are several options to weigh in relation to certain aspects (Saaty, 1982; Saaty & Vargas, 2012). The AHP method can be used in both social and physical areas to make measurements (Ozdemir, 2018).

The AHP method generally consists of the following five main steps:

1. Defining and hierarchically displaying the decision problem
2. Creating a pairwise comparison matrix
3. Determining weight
4. Performing a consistency assessment
5. Integrating weights and making a final decision

In order for the AHP to be applied, the decision problem and goal of the process must be clearly defined. An AHP structure consists of three main levels: goal, factors (criteria), and decision points (alternatives), where the point to be reached is defined as the goal. The decision problem is divided into sections to define the main criteria that must be met in the most general sense to achieve the main goal, and a hierarchy is created. After all the criteria at the lowest level have been worked through, the same process is repeated for the criteria at the higher level. This step is repeated until the main criteria, which are listed below the main objective, are also compared. All of the alternatives are then compared in pairs according to their performance on all criteria at the lowest level of the hierarchy, using pairwise comparisons to obtain the data. The matrix of pairwise comparisons is used to determine the priority of the decision criteria based on the judgment of the decision maker. In the pairwise comparison phase, two different judgment scales, Saaty's fundemental scale and the Balanced scale, were used. The purpose of using two different scales was to compare them and examine whether there is any valuable variation that could change the ranking of the alternatives. After the comparisons were made, the consistency ratios and the closeness of the priority vectors obtained with both scales between these two vectors according to the Saaty compatibility index and the Garuti (2017) compatibility index were examined.

In recent decades, several modifications of the AHP have been proposed. The pairwise comparison scale is one of the current topics of discussion when considering modifications and improvements (Goepel, 2019). The fundamental AHP scale proposed by Saaty (1980) consists of integer values from 1 to 9, whose verbal expressions can be seen in Table 2. With the real numbers used in this scale, an individual decision maker can accurately express his or her preference for all pairs of alternatives (Brunelli, 2015). The other proposed scales also contain a total of 9 numerical values corresponding to the same expressions. Essentially, these verbal comparisons are converted into proportional ratings through a one-to-one matching process with a numerical scale (Meesariganda & Ishizaka, 2017).

Goepel (2019) categorizes AHP scales into the following three groups:

Group 1: The maximum entry value in the pairwise comparison matrix is kept at nine as in Saaty's fundamental scale. The fundamental scale, the inverse linear scale, the balanced scale, and the generalized balanced scale are grouped in this category.

Group 2: The maximum range of input values in the pairwise comparison matrix is reduced to values less than nine. The logarithmic scale, square root scale and Koczkodaj scale are combined in this category.

Group 3: The maximum input values and the range of input values in the pairwise comparison matrix are increased to values higher than nine. The power scale, geometric scale, adaptive scale and adaptive-balanced scale are combined in this category.

Table 2
Verbal judgments equivalent to the Saaty's fundamental scale and the Balanced scale

Verbal expression of the scale	**Saaty's Fundamental scale**	**Balanced scale**
Equal importance	**1**	**1.00**
Weak/slight importance over another	**2**	**1.22**
Moderate importance over another	**3**	**1.50**
Moderate plus importance over another	**4**	**1.85**
Strong/essential importance over another	**5**	**2.33**
Strong importance over another	**6**	**3**
Very strong importance over another	**7**	**4**
Very strong to extreme importance over another	**8**	**5.67**
Extreme importance over another	**9**	**9.00**

Source: (Saaty, 2008; Meesariganda, & Ishizaka, 2017)

As can be seen in Table 2, the verbal expressions are presented on scales from 1 to 9. Which scale is better is still an open question, but it can be inferred that Saaty's fundamental AHP scale is not optimal, as all other scales seem to have some supporting evidence (Brunelli, 2015). Salo and Hämäläinen (1997) note that integers from 1 to 9 give uniformly distributed local weights, so there is no sensitivity in comparing items that are close to each other. Because of this fact, they proposed a Balanced scale (see Table 2) in which the local weights are evenly distributed over the weight range (Franek & Kresta, 2014).

The Balanced scale was proposed based on empirical experiments with humans and showed that a balanced scale increases the reliability of estimates and the overall consistency of the hierarchy evaluation process as well as reduces the dispersion of calculated weight values. (Brunelli, 2015). The scale function of this balanced scale is as follows (Goepel, 2019):

$$\boldsymbol{c = \frac{9 + x}{11 - x}}$$

The real values corresponding to the verbal judgments associated with the Balanced scale are shown in Table 2. In this article, pairwise comparisons were made by applying the fundamental and balanced scales to the same case study. Differences were examined to make a comparison between the two methods and determine if there was a greater variance affecting the decision-making process. Agreement with Saaty's and Garuti's priority compatibility index was then examined.

In addition, if the decision to be made at the end of a study is in a structure that will affect many people, pairwise comparison decision matrices are formed by combining the judgments of different people. In this process of combining judgements, many researchers suggest using the geometric mean method to obtain consistent pairwise comparison matrices.

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If the pairwise comparison that reflects the personal judgments of the decision-maker based on the scale 1-9 is represented by *A*, then a_{ij} indicates the importance of feature *i* according to feature *j*. The pairwise comparison matrix is obtained as follows when m indicates the number of criteria to be evaluated:

$$\text{When } A = \begin{bmatrix} a_{11} & a_{12} \cdots & a_{1n} \\ a_{21} & a_{22} \cdots & a_{2n} \\ \vdots & \vdots \ddots & \vdots \\ a_{m1} & \cdots \cdots & a_{mn} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1/a_{22} \cdots & & 1/a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & \cdots & \cdots & a_{mn} \end{bmatrix}, i,j = 1, \ldots, m, a_{ij} > 0,$$

If $a_{ij} = \frac{1}{a_{ji}}$ and $a_{ii} = 1$, $a_{ij} = a_{ik}a_{kj}$, $i,j,k = 1, \ldots, m$, equalities are provided, the matrix *A* is fully consistent; otherwise, it is inconsistent (Wang & Elhag, 2008).

Having defined the *A* matrix, its elements need be normalized by dividing the value of each element to the sum of the column. In a normalized matrix, significance values (weight values) are determined by calculating the arithmetic mean of each row. Given that b_j, *j* indicates the total value of a column, the total value of a column is calculated with the following formula:

$$b_1 = \sum_{i=1}^{m} a_{1i} \,.$$

Then, the elements of *A* matrix are divided by the total value of their column with the following formula:

$$c_{ij} = a_{ij}/b_i$$

As a result, matrix *C* with $m \times m$ dimension is found by normalizing the pairwise comparison matrix as follows:

$$C = \begin{bmatrix} c_{11} & c_{12} \cdots & c_{1n} \\ c_{21} & c_{22} \cdots & c_{2n} \\ \vdots & \vdots \ddots & \vdots \\ c_{m1} & \cdots \cdots & c_{mn} \end{bmatrix}.$$

C matrix helps specify relative percentage significance values (i.e. their weight values) of the criteria.

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

W column vector refers to the percentage weight of the criteria calculated with the arithmetic mean of the rows in a *C* matrix.

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_m \end{bmatrix}$$

The validity, and therefore factuality, of the results relies on the consistency of the pairwise comparison matrices. The consistency of results is confirmed with the consistency ratio (CR). A consistency analysis also helps highlight incorrect judgments and reduce errors. To measure the consistency of the pairwise matrices, the CR is calculated by dividing the consistency index (CI) by the random index (RI). To measure the CI, λmax defines the biggest eigenvalue of A matrix and is calculated with $(A - \lambda_{max} I)W = 0$, w = 0. RI is identified with the size of the pairwise matrix. The RI values from 1 to 10 are shown in Table 3.

$$CI = (\lambda_{max} - m)/m - 1 \quad , CR = \frac{CI}{RI}$$

Table 3
RI values

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rİ	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

If the CR value is less than 0.10, the comparisons of the decision makers are considered to be satisfactorily consistent; if not, they are inconsistent, which indicates that the AHP has not produced significant results (Lee, Mogi, Shin, & Kim, 2007). In another study, Saaty (1996) proposed 5% and 8% as thresholds for 3x3 and 4x4 matrices, respectively while keeping a 10% threshold for larger matrices.

3. Determining the preference order of GSM operators

Dündar & Fatih (2008) determined that mobile phone users consider the following criteria when choosing a GSM operator: call fee, coverage area, line fee and service quality. In another study by Yıldız (2019), product features, exterior, customer satisfaction and service were determined to be the most important factors in the selection of GSM operators.

The objective of the AHP model in this article is to "determine the GSM operator preference of university students." The structure of the decision hierarchy is seen in Figure 1 below.

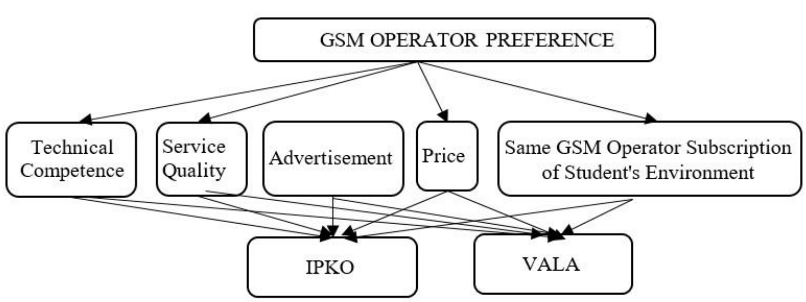

Figure 1 Structure of the decision hierarchy

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In order, to determine the students' GSM operator preference, which is the aim of the study, technical competence, service quality, advertising, price, and the use of the same operator in the student's environment were determined as the decision criteria to use in the AHP method.

In this study, we constructed the decision hierarchy in order to achieve a reasonable result. The pairwise comparisons were then created in accordance with the analysis of the alternatives. For this purpose, each GSM operator subscriber was asked to weight the criteria according to the degree of importance using Saaty's Fundamental scale (1997) and the Balanced scale. For these calculations, the evaluations of 100 students who are GSM operator subscribers were selected as samples and considered. Table 4 shows the pairwise comparison matrix that was created using Saaty's scale.

Table 4
Pairwise comparison matrix for criteria using Saaty's Fundamental scale

Criteria	Technical competence	Service quality	Advertisement	Price	Same GSM operator subscription by others in student's environment
Technical competence	1	2	2	1/2	1/2
Service quality	1/2	1	2	1/2	1/2
Advertisement	1/2	1/2	1	1/2	1/3
Price	2	2	2	1	1/2
Same GSM operator subscription by others in student's environment	2	2	3	2	1

The values of the pairwise comparison matrix adapted to the Balanced scale are shown in Table 5.

Table 5
Comparison matrix for criteria using the Balanced scale

Criteria	Technical competence	Service quality	Advertisement	Price	Same GSM operator subscription by others in student's environment
Technical competence	1	1.22	1.22	1/1.22	1/1.22
Service quality	1/1.22	1	1.22	1/1.22	1/1.22
Advertisement	1/1.22	1/1.22	1	1/1.22	1/1.5
Price	1.22	1.22	1.22	1	1/1.22
Same GSM operator subscription by others in student's environment	1.22	1.22	1.5	1.22	1

With the help of Expert Choice, the weights determined as a result of the comparisons made with both scales were calculated and are shown in Table 6. The weights of the alternatives were determined according to each criterion by going through similar processes.

Table 6
Weights of criteria computed with Saaty's Fundamental scale and Balanced scale

Criteria	*Weights and rank*			
	Saaty`s scale	Rank	*Balanced scale*	Rank
Technical competence	0.184	3	0.198	3
Service quality	0.138	4	0.183	4
Advertisement	0.095	5	0.162	5
Price	0.242	2	0.215	2
Same GSM operator subscription by others in student's environment	0.341	1	0.242	1
Consistency Ratio	*0.03*		*0.0025*	

As can be seen in Table 6, the distribution of weights found by Saaty's scale and the Balanced scale varies considerably, but the order of importance of the criteria is the same. The students reported that having the same operator was the most important criterion and the advertisement criterion was the least important. Although the order of the criteria is the same, the fact that the distribution of weights differed depending on the scales is due to the inconsistency accumulated in pairwise comparisons. As can be seen in this application, the pairwise comparison matrix created with the Balanced scale has significantly reduced the weight ratios of the criteria. For example, the relative ratio of the price and advertising criteria with Saaty's scale is (0.242/0.095) = 2.547 and for the Balanced scale is (0.215/0.162) =1.327. Although the absolute differences in the weight ratios are small and the ranks are the same, the only ratio that the AHP method takes into account is the relative ratio; therefore, the above comparison shows one of the situations where significantly different results can occur when different scales are used. To explain the importance of this weight distribution, for example, when the GSM operator in our study wants to allocate its budget according to these criteria, they will be able to make a better distribution of resources knowing these weights.

One of the important factors that the AHP considers is CR. If this ratio is less than 0.10, the pairwise comparison is valid. In his study, Yıldırım (2019) interpreted the performance of the scales using many scales and several performance measurement methods. Measured Scale Lower CR, which is one of the scale performance measurement methods used, represents the percentage of trials with lower CR values, and these values have been generated by the measured scale rather than Saaty's Fundamental Scale.

The fact that CR values resulting from the Balanced scale are lower than those from Saaty's scale does not prove that the Balanced scale is a better option. This is an expected result since the numbers in the Balanced scale matrix are generally closer together (that's why it is call balanced), thus they will generally achieve better consistency. If we change the numbers to those that are closer together, we will get an even better consistency. The closer the numbers, the better the CR; however, this is not an argument for choosing the Balanced scale. The goal is to not only achieve better consistency but to prove that the judgments are more representative and the final outcome is better (at least in most of the cases). In addition, the closeness of the priority vectors obtained with both scales according to the Saaty's compatibility index was examined. Even when vectors are not identical, they can sometimes be considered close to each other. According to Saaty (2005) "when two vectors are close, we say they are *compatible*". The Saaty compatibility index, *S*, was the first developed measure of compatibility between priority vectors. This index uses the concept of the Hadamard Product, the element-wise product of two matrices (Garuti, 2012).

The Saaty compatibility index, *S*, between vectors x and y is obtained with the following equation: $S = (1/n^2)e^T A \bullet B^T e$ where *n* is the number of elements of the vectors, **e** is a column-matrix with all elements equal to 1, $a_{ij} = x_i/x_j$, $b_{ij} = y_i/y_j$, and $\bullet$ is the Hadamard Product operator (Saaty, T. L.; Peniwati, K., 2013).

One desirable property of a consistency index is that it should indicate that a vector is completely compatible with itself. For identical vectors, $S = 1$. If $S \leq 1.1$ the two vectors are said to be compatible; otherwise, they are not.

The Garuti compatibility index, *G*, between vectors x and y is calculated using the equation below. This index is based on a physical interpretation of the inner product of

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two vectors, "x, y", given by |x||y| cos α, where α is the angle between vectors x and y. For identical normalized vectors, α = 0 and 'x, y' = 1. For perpendicular (orthogonal) vectors, α = 90° and 'x, y' = 0. For identical normalized vectors, G = 1, which means total compatibility. The smallest possible value is G = 0, which means total incompatibility.

$$\boldsymbol{G} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{n}} \left[\frac{\mathbf{min}(\boldsymbol{x_i}, \boldsymbol{y_i})}{\mathbf{max}(\boldsymbol{x_i}, \boldsymbol{y_i})} \frac{(\boldsymbol{x_i} + \boldsymbol{y_i})}{\boldsymbol{2}} \right]$$

If G< 0.9, Garuti (2017) proposes that x and y should be considered not compatible.

Table 6 shows two priority vectors obtained for the criteria using Saaty's scale and the Balanced scale. The corresponding elements of vector 1 and 2 appear close to each other based on a cursory examination of the differences between them. So, S = 1.096 for vectors 1 and 2 indicates that they are indeed compatible.

G=78.38% indicates that these two vectors are not compatible. The lower threshold for G is 90%); therefore, they are far from compatible. A mathematical simulation should be performed to investigate whether G < 0.9 can be tolerated for vectors with higher n, as has been done for the consistency index (Garuti & Salomon, 2012).

Table 7
Weights of alternatives computed with Saaty's Fundamental scale and Balanced scale

Alternative	Weighs and ranks			
	Saaty`s scale	Rank	Balanced scale	Rank
VALA	0.378	2	0.469	2
IPKO	0.622	1	0.531	1

Similarly, Table 8 shows that although the weights of the alternatives are different, IPKO is the more preferred GSM operator by the students. If we look at the relative ratios, IPKO and VALA weights ratios were 0.622/0.378 with Saaty's scale, and this ratio was 0.469 for VALA and 0.531 for IPKO with the Balanced scale. Since there are only two options here, there is no inconsistency, so the CR values are not compared.

Table 7 shows two priority vectors determined for the alternatives using Saaty's Fundamental scales and the Balanced scale. The corresponding elements of vectors 1 and 2 appear to be close to each other based on a cursory examination of the differences between them. Therefore, S = 1.035 for vectors 1 and 2 indicates that they are indeed compatible. G=83.3% < 90% indicates that these two vectors are not compatible; therefore, they are far from being compatible.

As a result of this research, the opinions of the subscribers of GSM operators in Kosovo about two GSM operators were determined through the analysis including a survey, and a GSM operator ranking was obtained from the perspective of the subscribers. There is full consistency as the consistency ratios of the criteria and options were far less than 10%.

4. Conclusions

In the use of communication tools, the expectations and preferences of subscribers differ. Since university students constitute a significant portion of the population using communication tools, their preference for the actively operating GSM operators (VALA, IPKO) was determined using the AHP method.

In the study, six decision criteria that students consider when choosing a GSM operator were determined. These chosen criteria were technical competence, service quality, advertisement, price, and same GSM operator subscription used by others in the student's environment. Students made pairwise comparisons of these decision criteria and GSM operators according to each decision criterion based on the importance level of the AHP method. These pairwise comparisons were evaluated using two different scales: Saaty's Fundamental scale and the Balanced scale. Then, the weight scores of the decision criteria of the students, which were obtained from the pairwise comparisons made with both scales, were determined and the comparison was made. During the evaluation, inconsistencies were checked for both scales and it was concluded that the Balanced scale had more consistent results in terms of scale performance (Pöyhönen, Hämäläinen, & Salo, 1997). When the results were examined, although the ranks obtained with both scales were the same, differences were observed in the weight distributions. Since the weights of the decision-making elements are often more important than their ranking in allocation problems, it is important which scale was used and additional analysis is needed to make a final decision. As can be seen from Table 4, the weight distribution of the criteria obtained with the Balanced scale in this application has been significantly lightened (this is not necessarily an advantage). One may have many ways to get a lightened distribution of the weights, but that is not a sufficient motive for choosing the Balanced scale. This "lightened process" can introduce some bias to the results.

The use of the Balanced scale instead of the original Fundamental scale in the AHP standard process during the determination of the most appropriate GSM operator preference shows that the AHP is robust and reliable as a method to support the decision-making process even when the decision scale is changed. As a result, IPKO was the first preferred operator and VALA was the second preferred GSM operator by the students.

Also, the first measure of compatibility between priority vectors was developed by Saaty and it uses the concept of the Hadamard Product, which is the elemental product of two matrices. Garuti (2007) proposed a different G-index of compatibility based on the Inner Product's physical interpretation, including the vector projection concept. When two vectors are the same, the threshold $S = 1$. $S \leq 1.1$ is set as an upper bound for congruent vectors. One issue with Saaty's compatibility index is that under certain circumstances, the upper threshold might change to 1.01.

Tables 6 and 7 show the comparison of two priority vectors obtained using Saaty's Fundamental scale and the Balanced scale for criteria and alternatives, respectively. The

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compatibility of the two priority vectors is calculated using both Saaty's and Garuti's compatibility indices. For the priority vectors of criteria, the result of the Garuti index is 78.38% which shows that the two vectors are not compatible with the threshold being 90%. However, the result of the Saaty index is 1.096, which is less than the threshold of 1.1, indicating that the two priority vectors are compatible according to the Saaty compatibility index.

For the priority vector of alternatives, the result of the Garuti index is 83.3%, which is below the threshold of 90%, indicating that the two vectors are incompatible. On the other hand, the result of the Saaty index is 1.035, which is less than the threshold of 1.1, indicating that the two priority vectors are compatible according to the Saaty compatibility index. A mathematical simulation is needed to determine if a G value below 90% can be tolerated for higher n vectors, as is done for the consistency index (Garuti & Salomon, 2012).

Subsequent studies should focus on the use of different scales in different decision-making problems. In order to determine the best approach, an application in a real-life problem as in this study is recommended or a mathematical programming and simulation in which the results for all judgment scales are compared.

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