



2nd International Conference on Information Technology and Quantitative Management,
ITQM 2014

Business mobile-line selection in Turkey by using fuzzy TOPSIS, one of the multi-criteria decision methods

Irfan Ertugrul^a, Tayfun Oztas^{b,*}

^{a, b}*Pamukkale University, Economics and Administrative Sciences Faculty, Business Administration Department, Denizli, 20040, Turkey*

Abstract

Nowadays, businesses are growing day by day. The executives of these growing businesses have to be nested with business operations to get more profits, to increase customer satisfaction, and to create quick solutions for possible problems. Therefore, businesses benefit from mobile operators' institutional solutions for their executives to communicate with each other in any expected time and place and to obtain any data about business.

In this paper, it is benefitted from fuzzy logic concept based on individual knowledge and experiences to select mobile line that offers the most economic, the best and the most suitable solutions for the business needs, between the choices for the businesses. In fuzzy logic, criteria and alternatives can be evaluated incrementally by linguistic variables and membership functions and there is a soft transition than classical logic between concepts. In the selection of corporate mobile line, decision making business mobile-line, decision making process is handled by using fuzzy logic approach for the personal preferences which are difficult to express numerically

© 2014 Published by Elsevier B.V. Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).

Selection and peer-review under responsibility of the Organizing Committee of ITQM 2014.

Keywords: Multi-criteria decision making; Fuzzy Logic; Fuzzy TOPSIS; Business mobile line.

* Corresponding author. Tel.: +90 258 269 26 32
E-mail address: toztas@pau.edu.tr

1. Introduction

Mobile phones have become an important innovation in terms of business executives. Mobile phones have been cheaper importantly. Low-priced mobile phones have been common in an easier way than the other technologies in developing countries. Popularization of mobile phones is a great improvement which gives important advantages to small businesses¹. Turkey's first GSM operator started to work in 1994². In time, the number of operators and also the number of subscribers have increased. There are three active operators in Turkey nowadays. From September in 2013 till now, Turkey has about 91% of penetration rate and 68,911,173 mobile phone subscribers. The rate of personal subscribers is 91.1% and rate of business subscribers is 8.9% in total subscribers³. These data show how common using mobile phone is.

As businesses grow, their executives have to be nested with their business continuously. Therefore, businesses benefit from institutional solutions of GSM operators to get more profits, to increase customer satisfaction, to get quick solutions for possible problems, to access any data in anywhere or every time and to enable the executives to communicate with each other. In this study, it is aimed to be chosen of institutional line with internet (mobile internet), mobile text and mobile call which are the most economic, the most suitable for business objectives, which enable the best solution among the lines offered by GSM operators. One of the Multi Criteria Decision Methods, Fuzzy TOPSIS is used for selecting business mobile line to be able to consider decision makers individual experiences.

2. Fuzzy Logic and Fuzzy TOPSIS

Lotfi Zadeh introduced Fuzzy Logic concept to the world in the early 1960. Via this invention he states to be able to get a connection between human intelligence and linguistic concepts by the help of mathematics. Some concepts can be defined with words better than mathematical expressions. So better models can be established with fuzzy logic and fuzzy sets in comparison with classical sets⁴. As classical logic deals with only true or false concepts, fuzzy logic deals with partly true or partly false concepts.

Main features of fuzzy logic as below:

- Everything has a degree in fuzzy logic
- Any system can be fuzzified
- In fuzzy logic, exact values is seen as a limiting case for approximate values⁵

Fuzzy logic is based on fuzzy sets. Fuzzy sets transform verbal expressions to mathematical expressions by linguistic variables. Supposed that A is a fuzzy set in X universal set, elements of A will be in [0, 1] interval. Membership degrees (μ) of elements in a fuzzy set are determined by membership functions. If the value of this function equals to 1, that element has a full membership to fuzzy set, similarly if the value of function equals to 0, that element doesn't belong to the set⁶.

Membership functions can have definite shapes according to mathematical rules used. The most commonly used membership functions are triangular, trapezoidal, Gaussian according to their shapes⁷. In this paper, triangular membership function is used for convenience in computing. A triangular membership function can be shown with a_1, a_2, a_3 as in figure 1.

People have to decide about a lot of things to do in their daily lives. For example; a business has to decide on a lot of matters from location decision to supplier selection. The main aim of decision making in similar subjects is to supply business needs. Multi criteria decision making methods are used widely in selection according to the needs among the alternatives. This method is a discipline including mathematics, management, informatics, psychology, social sciences and economics⁸.

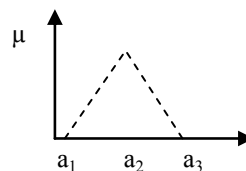


Fig. 1. Triangular Membership

One of the Multi Criteria Decision Methods, TOPSIS Methods needs only a few inputs from the users and its output is easy to understand. The main aim of the method is to get the solution which has the shortest distance to the positive ideal solution and get the solution which has the furthest distance to the negative ideal solution⁸. In this paper, Fuzzy TOPSIS method is used for benefitting from the experiences based on personal knowledge. Fuzzy TOPSIS method transforms decision makers’ views about criteria and alternatives to fuzzy numbers and then ranks them according to the shortest distance to ideal solutions. The results of the ranking determine the selection. The

Fig. 1: Triangular Membership linguistic variables and their triangular fuzzy number values which are used for evaluating criteria and alternatives in Fuzzy TOPSIS method as below:

Table 1: Linguistic variables and their fuzzy number values of criteria

Linguistic Variable	Fuzzy Value
Very Low	(0, 0, 0.2)
Low	(0, 0.2, 0.4)
Medium	(0.3, 0.5, 0.7)
High	(0.8, 0.8, 1)
Very High	(0.8, 1, 1)

Table 2: Linguistic variables and their fuzzy number values of alternatives

Linguistic Variable	Fuzzy Value
Very Low	(0, 0, 2)
Low	(0, 2, 4)
Medium	(3, 5, 7)
High	(6, 8, 10)
Very High	(8, 10, 10)

Method’s algorithm as below:

Step 1: Assume that x_{ij}^K shows value of alternative i. In a group consists of K decision makers, criteria values of alternatives calculated as ($x_{ij} = (a_{ij}, b_{ij}, c_{ij})$):

$$x_{ij}^K = [x_{ij}^1 + x_{ij}^2 + \dots + x_{ij}^K] \frac{1}{K} \tag{1}$$

Step 2: Assume that w_{ij}^K shows weight of importance criteria j. In a group consists of K decision makers, importance weight of criteria calculated as ($w_{ij} = (a_{j1}, b_{j2}, c_{j3})$):

$$w_{ij}^K = [w_{ij}^1 + w_{ij}^2 + \dots + w_{ij}^K] \frac{1}{K} \tag{2}$$

In a Multi Criteria Decision Making problem decision and weight matrices as below m: number of alternatives, n: number of criteria):

$$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & \dots & \dots & x_{mn} \end{bmatrix} \quad W = [w_1, w_2, \dots, w_n]$$

Step 3: Normalization of decision matrix can be computed with two ways according to benefit or cost criteria.

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), j \in B, c_j^* = \max_i c_{ij} \tag{3}$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), j \in B, a_j^- = \min_i a_{ij} \tag{4}$$

Hereby, c_j^* is maximum value of fuzzy numbers' third parameters in a column, a_j^- is minimum value of fuzzy numbers' first parameters in a column.

Step 4: Normalized with weights of decision makers' preference decision matrix as below, calculated fuzzy number is in [0, 1] interval

$$V_{ij} = r_{ij} \times w_j \tag{5}$$

Step 5: Fuzzy positive ideal solution is defined as $A^* = (V_1^*, V_2^*, \dots, V_n^*)$ and similarly, fuzzy negative ideal solution is defined as $A^- = (V_1^-, V_2^-, \dots, V_n^-)$. Hereby, v_j^* and v_j^- equal (1, 1, 1) and (0, 0, 0) respectively. There are same numbers of criteria, (1, 1, 1) and (0, 0, 0). Distances of alternatives to positive and negative solutions as below:

$$d_i^* = \sum_{j=1}^n d(v_{ij}, v_j^*), i = 1, 2, \dots, m \tag{6} \quad d_i^- = \sum_{j=1}^n d(v_{ij}, v_j^-), i = 1, 2, \dots, m \tag{7}$$

Distance between two fuzzy numbers can be calculated as below:

$$d(a, b) = \sqrt{\frac{1}{3} [(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \tag{8}$$

Step 6: Using calculated distance coefficients is made a ranking. The biggest distance coefficient is selected as best alternative.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{9}$$

3. Application

In business mobile line selection, five alternatives are chosen by tariff data from three main GSM operators' websites in Turkey. As alternative tariffs are chosen, the tariffs with similar prices and features are selected for decision makers to be able to make decisions more consistently. The reasons for selection of criteria can be put into order as below:

- *Call Time (Other Mobile Networks)*: When examining GSM operators’ tariffs, it is seen call times are unlimited in the same mobile networks generally. So, for the decision makers to have a selection, it is selected call time to the other mobile networks that vary among tariffs.
- *Mobile Internet*: Nowadays, majority of works are carried out via e-mails in businesses so internet packages are of great importance for the executives to follow e-mails when they are out of their offices.
- *Text*: It loses its popularity because of using the internet commonly. But, because there are a lot of text users, it takes a place among the criteria.
- *Commitment Period*: GSM operators offer several discounts at certain rates to the businesses which make a contract for a period; but when businesses want to retract the contracts because of incorrect preferences, huge amount of money has to be paid for it.
- *Price*: Price is the most important criteria however tariff contents vary in time.

In application of this paper, criteria and alternatives are asked to executives of four active businesses in Denizli-Turkey. The executives evaluate the options with linguistic variables such as very low, low, medium, high, very high according to their knowledge and experiences. The evaluated alternatives and the criteria are modeled by triangular fuzzy numbers and it is aimed to choose the appropriate mobile line and tariff for business.

In the selection of business mobile line, it is asked to the decision makers about the criteria in the tariff and asked how important those criteria are for them and the answers are as in Table 3 and fuzzy values of these answers are as in Table 4.

Table 3: Importance of criteria for decision makers

	Call Time	Mobile Internet	Text	Commitment Period	Price
DM 1	Very High	Very High	Medium	Very High	Very Low
DM 2	High	Medium	High	Medium	Medium
DM 3	High	Low	Low	High	Medium
DM 4	Very High	High	Medium	Very High	Very Low

Table 4: Fuzzy Values of Criteria

	Call Time	Mobile Internet	Text	Commitment Period	Price
DM 1	(0.8, 1, 1)	(0.8, 1, 1)	(0.3, 0.5, 0.7)	(0.8, 1, 1)	(0, 0, 0.2)
DM 2	(0.8, 0.8, 1)	(0.3, 0.5, 0.7)	(0.8, 0.8, 1)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)
DM 3	(0.8, 0.8, 1)	(0, 0.2, 0.4)	(0, 0.2, 0.4)	(0.8, 0.8, 1)	(0.3, 0.5, 0.7)
DM 4	(0.8, 1, 1)	(0.8, 0.8, 1)	(0.3, 0.5, 0.7)	(0.8, 1, 1)	(0, 0, 0.2)
Average(w_j)	(0.8, 0.9, 1)	(0.48, 0.63, 0.78)	(0.35, 0.5, 0.7)	(0.68, 0.83, 0.93)	(0.15, 0.25, 0.45)

Information about business mobile lines was collected from operators’ web sites. Decision makers’ individual evaluations about these mobile lines and their fuzzy values are shown as below tables ^{9, 10, 11}.

Table 5: Information about business mobile line

	Call time (Min)	Mobile Internet (GB)	Text	Commitment Period (Year)	Monthly Price (TRY)
Alternative 1	1000	1	1000	1	48.75
Alternative 2	2000	2	2000	0	55
Alternative 3	300	1	500	2	75

Table 6: Linguistic variables about mobile lines

		DM 1	DM 2	DM 3	DM 4
Call Time	Alternative 1	Medium	High	Medium	Low
	Alternative 2	High	Very High	High	Medium
	Alternative 3	Very Low	Low	Low	Very Low
Mobile Internet	Alternative 1	Very Low	Medium	Low	Low
	Alternative 2	Very Low	High	Medium	Medium
	Alternative 3	Very Low	Medium	Very Low	Low
Text	Alternative 1	High	Medium	Medium	High
	Alternative 2	Very High	High	High	Very High
	Alternative 3	High	Low	Very Low	High
Commitment Period	Alternative 1	Very Low	Low	Low	Very Low
	Alternative 2	Very Low	High	Very High	Very High
	Alternative 3	Medium	Medium	Medium	Low
Monthly Price	Alternative 1	Medium	Medium	Medium	Very High
	Alternative 2	Medium	Low	Low	High
	Alternative 3	Low	Very Low	Low	High

Table 7: Fuzzy Values of linguistic variables

		DM 1	DM 2	DM 3	DM 4	Average
Call Time	Alternative 1	(3, 5, 7)	(6, 8, 10)	(3, 5, 7)	(0, 2, 4)	(3, 5, 7)
	Alternative 2	(6, 8, 10)	(8, 10, 10)	(6, 8, 10)	(3, 5, 7)	(5.75, 7.75, 9.25)
	Alternative 3	(0, 0, 2)	(0, 2, 4)	(0, 2, 4)	(0, 0, 2)	(0, 1, 3)
Mobile Internet	Alternative 1	(0, 0, 2)	(3, 5, 7)	(0, 2, 4)	(0, 2, 4)	(0.75, 2.25, 4.25)
	Alternative 2	(0, 0, 2)	(6, 8, 10)	(3, 5, 7)	(3, 5, 7)	(3, 4.5, 6.5)
	Alternative 3	(0, 0, 2)	(3, 5, 7)	(0, 0, 2)	(0, 2, 4)	(0.75, 1.75, 3.75)
Text	Alternative 1	(6, 8, 10)	(3, 5, 7)	(3, 5, 7)	(6, 8, 10)	(4.5, 6.5, 8.5)
	Alternative 2	(8, 10, 10)	(6, 8, 10)	(6, 8, 10)	(8, 10, 10)	(7, 9, 10)
	Alternative 3	(6, 8, 10)	(0, 2, 4)	(0, 0, 2)	(6, 8, 10)	(3, 4.5, 6.5)
Commitment Period	Alternative 1	(0,0, 2)	(0,2, 4)	(0,2, 4)	(0,0, 2)	(0, 1, 3)
	Alternative 2	(0, 0, 2)	(6, 8, 10)	(8, 10, 10)	(8, 10, 10)	(5.5, 7, 8)
	Alternative 3	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(0, 2, 4)	(2.25, 4.25, 6.25)
Monthly Price	Alternative 1	(3, 5, 7)	(3, 5, 7)	(3, 5, 7)	(8, 10, 10)	(4.25, 6.25, 7.75)
	Alternative 2	(3, 5, 7)	(0, 2, 4)	(0, 2, 4)	(6, 8, 10)	(2.25, 4.25, 6.25)
	Alternative 3	(0, 2, 4)	(0, 0, 2)	(0, 2, 4)	(6, 8, 10)	(1.5, 3, 5)

Decision matrix and weighted normalized decision matrix are created as in table 8 and table 9 according to this information.

Table 8: Decision matrix

	Call time (Min)	Mobile Internet (Gb)	Text	Commitment Period (Year)	Monthly Price (TRY)
Alternative 1	(3, 5, 7)	(0.75, 2.25, 4.25)	(4.5, 6.5, 8.5)	(0,1, 3)	(4.25, 6.25, 7.75)
Alternative 2	(5.75, 7.75, 9.25)	(3, 4.5, 6.5)	(7, 9, 10)	(5.5, 7, 8)	(2.25, 4.25, 6.25)
Alternative 3	(0, 1, 3)	(0.75, 1.75, 3.75)	(3, 4.5, 6.5)	(2.25, 4.25, 6.25)	(1.5, 3, 5)
Weights	(0.8, 0.9, 1)	(0.48, 0.63, 0.78)	(0.35, 0.5, 0.7)	(0.68, 0.83, 0.93)	(0.15, 0.25, 0.45)

Table 9: Weighted normalized decision matrix

	Call time (Min)	Mobile Internet (Gb)	Text	Commitment Period (Year)	Monthly Price (TRY)
Alternative 1	(0.26, 0.49, 0.76)	(0.06, 0.22, 0.51)	(0.16, 0.33, 0.6)	(0, 0.11, 0.35)	(0.03, 0.06, 0.16)
Alternative 2	(0.5, 0.76, 1)	(0.22, 0.43, 0.78)	(0.25, 0.45, 0.7)	(0.47, 0.73, 0.93)	(0.04, 0.09, 0.3)
Alternative 3	(0, 0.1, 0.32)	(0.06, 0.17, 0.45)	(0.11, 0.23, 0.46)	(0.19, 0.44, 0.73)	(0.05, 0.13, 0.45)

Distances to positive and negative ideal solutions are calculated according to linguistic variables used by decision makers. For ranking these distances coefficients are given in table 10.

Table 10: Distances to positive and negative solutions

	di*	di-	CC
Alternative 1	2.92	2.4	0.45
Alternative 2	1.98	3.4	0.63
Alternative 3	3.27	2.08	0.39

4. Conclusion

Businesses can analyse complicated problems by using computers and by multi criteria decision making methods. For instance, a basic level decision support system is developed by using Microsoft Office Excel program in this paper and it is aimed to automatize the business mobile line selection process for businesses in Turkey. Businesses can decide effectively with low costs about selection issues with the help of these basic programs.

It is asked to totally four executives of business operating in Turkey, three of which are active alternatives, two of which are about textile in Denizli - Turkey, one of which produces copper materials and one of which produces plastic materials. When evaluating alternatives criteria, related to call duration, Alternative 2 with 2000 minute option is seen advantageous. This factor also reflects the evaluation of decision makers. When analyzing the used linguistic variables, it is seen that these variables are evaluated more positively than the two other alternatives.

When caring internet packages in business mobile lines, the alternative 2 may be accepted to serve with 2 gigabyte (GB) to the users more usefully while the alternatives with the numbers 1 and 3 are serving an internet package with 1 GB. When glancing at text packages each alternative is seen to serve different quantities of text. Submitting the best quantity of text, the alternative 2 is assessed by decision makers as more positively. When looking at the criteria for commitment period, the alternatives are seen to prefer a commitment period between 0-2 years and this period is seen to affect adversely to the decision makers preferences with the length of commitment periods. When caring monthly using prices, prices are seen to vary between 48.75 Turkish Lira (TRY) and 75 Turkish Lira (TRY), because monthly prices are cost factors, decision makers are seen to tend to low-cost mobile lines as long as price increases.

Consequently, services presented by the alternatives are evaluated particularly according to the criteria. According to criteria evaluation, alternative 2 is seen to be more optional for businesses. Four executives are asked personal ideas. Their linguistic variables are seen to be the same with results of Fuzzy TOPIS method. So it can be said that the calculations used in this paper are consistent.

References

- Öztürk TC. The impact of the mobile telephone on development: Behavioral change in small business entrepreneurs in Turkey, PhD Thesis, Tulane University; 2006, p. 1.
- Wikipedia. Available at: <http://tr.wikipedia.org/wiki/Turkcell> (14.02.2014).
- Information and Communications Technologies Authority of Turkey, "Electronic Communication Market Data" ; 2013. Available at: <http://www.tk.gov.tr/kutuphane_ve_veribankasi/pazar_verileri/ucaylik13_3.pdf>
- McNeill FM, Thro E. *Fuzzy Logic a Practical Approach*. London: Academic Press Limited; 1994.
- Zadeh LA. Knowledge Presentation In Fuzzy Logic. In: Yager R, Zadeh LA, editors. *An Introduction to Fuzzy Logic Applications in Intelligent Systems*. New York: Springer Science and Business Media; 1992, p. 1-25.
- Paksoy T, Pehlivan NY, Ozceylan E. *Bulanık Küme Teorisi*. Ankara: Nobel; 2013.
- Sen Z. *Mühendislikte Bulanık Mantık ile Modelleme Prensipleri*. Istanbul: Su Vakfı Yayınları; 2004.
- Ishizaka A, Nemery P. *Multi-Criteria Decision Analysis Methods and Software*. West Sussex: John Wiley and Sons; 2013.
- Vodafone. Available at < <http://www.vodafone.com.tr/Is-Ortagim/Hersey-Dahil-Paketler-Indirim-Kampanyasi.php>> (17.02.2014).
- Avea. Available at <<http://www.avea.com.tr/web/biz/KonusMesajlas/Tarifeler/PrestijMenu>> (17.02.2014).
- Turkcell. Available at <<http://www.turkcell.com.tr/kurumsal/paket-ve-tarifeler/full-ve-super-paketler/super-eko-paket>>(17.02.2014).