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A New Approach of Neutrosophic Soft Set with Generalized Fuzzy TOPSIS in Application of Smart Phone Selection

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Abstract: With the invention of new technologies, the competition elevates in market. Therefore, it creates more difficulties for consumer to select the right smart phone. In this paper, a new approach is proposed to select smart phone, in which environment of decision-making is MCDM. Firstly, an algorithm is proposed in which problem is formulated in the form of neutrosophic soft set and then solved with generalized fuzzy TOPSIS (GFT). Secondly, rankings are compared with [10]. Finally, it is concluded that proposed approach is applicable in decision-making where uncertainty and imprecise information-based environment is confronted. In future, this evolutionary algorithm can be used along with other methodologies to solve MCDM problems.

Keywords: Accuracy Function, MCDM, TOPSIS, Mobile Phone, Soft set, Neutrosophic Numbers NNs, Neutrosophic Soft set, Linguistic Variable.

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1. Introduction

Mobile / cell phones are widely used for making call, SMS, MMS, email or to access internet. The first portable cell phone was manifest by Martin in 1973 [8], using a handset weighing 4.4 IBS. In the advance world, smart-phone have currently overtaken the usage of earlier telecommunication system. There may be an outstanding doubt and complications concerning the reputation of cellular technologies by decision makers, provider, trader, and clients alike. To help this selection process amongst different available options for technology evaluation, multi-standards decision-making approach appears to be suitable. Due to brutal market competition by inventions of different models with innovative designs and characteristics have made the buying decision making more complex [10]. It is typically tough for a decision-maker to assign a particular performance rating to another for the attributes into consideration. The advantage of employing a fuzzy approach is to assign the relative importance of attributes victimization fuzzy ranges rather than a particular number for textile the $64000 world during a fuzzy atmosphere. MCDM approach [9] with cluster deciding is employed to judge smartphones as another per client preferences [6]. TOPSIS methodology is especially appropriate for finding the cluster call –making drawback beneath fuzzy atmosphere. TOPSIS methodology [22] is predicated on the idea that the chosen various ought to have the shortest distance from the positive ideal solution. In decision making problems TOPSIS method have been studied by many researchers: Adeel et al. [3-5, 7 ,11, 13, 18, 21, 24]. This technique of MCDM is used by Saqlain et. al. [16] to predict CWC 2019. Maji [12] introduced the idea of Neutrosophic soft set. Riaz and

Naeem [14, 15] presented some essential ideas of soft sets together with soft sigma algebra. Neutrosophic set could be a terribly powerful tool to agitate incomplete and indeterminate data planned by F. Smarandache [20] and has attracted the eye of the many students [1], which might offer the credibleness of the given linguistic analysis worth and linguistic set can offer qualitative analysis values. At the primary, soft set theory was planned by a Russian scientist [2] that was used as a standard mathematical mean to come back across the difficulty of hesitant and uncertainty [19]. He additionally argues that however, the same theory of sentimental set is free from the parameterization inadequacy syndrome of fuzzy set theory [23], rough set theory, and applied mathematics. Nowadays, researchers are focusing to present new theories to deal with uncertainty, imprecision and vagueness [25-35], along with suitable examples to elaborate their theories. Neutrosophic soft sets along with TOPSIS technique is widely used in decision making problems, every day many researchers are working in this era [36-45] to discuss the validity of Neutrosophy in decision problems.

1.1 Novelties

It is a very complicated decision to select the utmost suitable phone. In this condition Neutrosophic soft-set-environment is considered and simplified with Generalized TOPSIS. An algorithm is proposed to tackle uncertain, vague and imprecise environment in selection problems.

1.2 Contribution

Cell phone selection is a challenging problem in current generation. To solve this complexity, a few methods regarding the usage of fuzzy ideas has been proposed. For the few kinds of uncertainty within the selection method fuzzy linguistic method is used. The objective of the study is to investigate the uncertainty in selection criteria of cell phone with respect to the consumer's choice under Neutrosophic softset environment by applying Generalized fuzzy TOPSIS.

2.Preliminaries

Definition 2.1: Neutrosophic Set [2]

Let U be a universe of discourse then the neutrosophic set A is an object having the form

$$A = \{< x:\ T_A\ (x), I_A(x), F_A\ (x), >; x \in U\}$$

where the functions $T, I, F : U \rightarrow [0,1]$ define respectively the degree of membership, the degree of indeterminacy, and the degree of non-membership of the element $x \in X$ to the set A with the condition. $\leq T_A\ (x) + I_A\ (x) + F_A\ (x)\ \leq 3$.

Definition 2.2: Soft Set [2]

Let $\mho$ be a universe of discourse, $P(\mho)$the power set of $\mho$, and A set of parameters. Then, the pair (F, $\mho$), where

$$F :\ A \longrightarrow P(\mho)$$

is called a softset over $\mho$.

Definition 2.3: Neutrosophic Soft Set [12]

Let $\mho$ be an initial universal set and E be a set of parameters. Assume, $A \subset E$. Let $P(\mho)$denotes the set of all neutrosophic sets over $\mho$, where F is a mapping given by

$$F :\ A \longrightarrow P(\mho)$$

Definition 2.4: Accuracy Function [17]

Accuracy function is used to convert neutrosophic number NFN into fuzzy number (Deneutrosophication using $\boldsymbol{A_F}$). $\mathrm{A(F)} = \{\, x = \frac{[T_x + I_x + F_x]}{3} \,\}$

$\boldsymbol{A_F}$ represents the De-Neutrosophication of neutrosophic number into Fuzzy Number.

3. Calculations

In this section an algorithm is proposed to solve MCDM problem under neutrosophic environment.

3.1 Algorithm

Cell phone selection is a challenging problem in current generation. To solve this complexity, a few methods regarding the usage of neutrosophic fuzzy TOPSIS ideas have been proposed. For the few kinds of uncertainty within the selection method fuzzy linguistic method is used. The objective of the study is to investigate the uncertainty in selection criteria of cell phone.

To solve this problem following algorithm is applied as in sequence.

Step 1: defining a problem

Step 2: Consideration of problem as MCDM (alternatives and attributes)

Step 3: Assigning linguistic variables to alternatives and criteria's / attributes

Step 4: Substitution of NNs to linguistic variables

Step 5: Conversion of NNs to fuzzy numbers by using accuracy function [?] defined as,

$$\mathrm{A(F)} = \{\, x = \frac{[T_x + I_x + F_x]}{3} \,\}$$

$Where\ T_x, I_x, F_x \in NNs\ assigned\ by\ decision\ makers\ to\ each\ criteria\ individually$

Step 6: Apply TOPSIS technique

Step 7: Arrange by ascending order and rank accordingly.

Step 8: Discussion

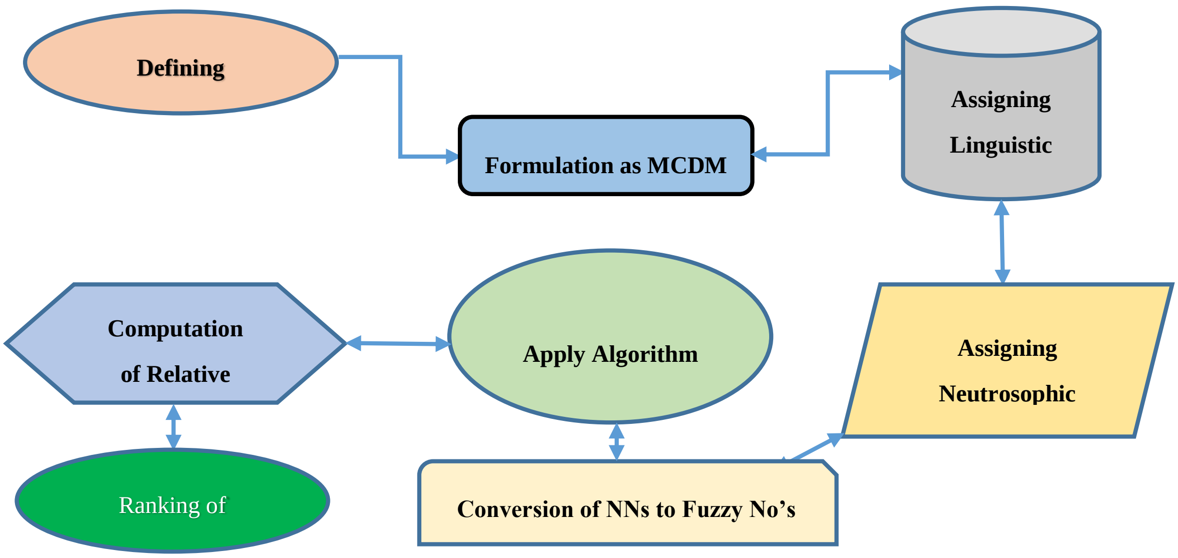

Figure 1: Algorithm used in mobile selection, under neutrosophic softset environment

3.2: Case Study

To discuss the;

- Validity
- Applicability

of the proposed algorithm, mobile selection is considered as a MCDM problem.

3.2.1 Problem Formulation

The mobile phone has been identified for choosing criterion and after that the criterion is depending upon the public choice. The result gets from criterion, some mobile phone has been selected according to their criterion. With invention of new technologies, the competition is raised upon in market it makes more difficult for consumer to select the right phone. In fast growing market, we think that the result got from fuzzy idea has been improved, so we applied Neutrosophic set to get more accuracy in result. The aim of the study is to explore the accuracy in the selection of criteria of mobile phone.

3.2.2 Parameters

Selection is a complex issue, to resolve this problem criteria and alternative plays an important role. Following criteria and alternatives are considered in this problem formulation.

Criteria's						
$\acute{C}_1$	$\acute{C}_2$	$\acute{C}_3$	$\acute{C}_4$	$\acute{C}_5$	$\acute{C}_6$	$\acute{C}_7$
Ram	Rom	Processor	Camera	Display Size	Model	Price

Mobiles as Alternatives					
$\d{M}_1$	$\d{M}_2$	$\d{M}_3$	$\d{M}_4$	$\d{M}_5$	$\d{M}_6$
SAMSUNG	NOKIA	HTC	HUAWEI	Q-MOBILE	RIVO

3.2.3 Assumptions

The decision makers $\{Ɗ_1, Ɗ_2, Ɗ_3, Ɗ_4\}$ will assign linguistic values from Table .1 according to his own interest, knowledge and experience, to the above-mentioned criteria and alternatives and shown in Table.2.

Table 1: Linguistic variables, codes and neutrosophic numbers obtained by expert opinion

Sr # No	Linguistic variable	Code	Neutrosophic Number
1	Very Low	$\tilde{V}\bar{\d{L}}$	(0.1, 0.3,0.7)
2	Low	$\bar{\d{L}}$	(0.3,0.5,0.6)
3	Satisfactory	Ş	(0.5,0.5,0.5)
4	High	Ḫ	(0.7,0.3,0.4)
5	Very High	$\tilde{V}$ Ḫ	(1.0,0.1,0.2)

3.3 Application of Proposed Algorithm

Step 1: Problem consideration 3.2.

Step 2: Formulation and assumptions 3.2.1 and 3.2.2.

Step 3: Assigning linguistic variables to each alternatives and criteria's / attributes.

Table 2: Each decision maker, will assign linguistic values to each attribute, from Table .1

	Strategies	$Ɗ_1$	$Ɗ_2$	$Ɗ_3$	$Ɗ_4$
$Ƈ_1$= RAM	$Ṃ_1$	ṼḸ	Ṣ	Ḫ	Ṣ
	$Ṃ_2$	Ḹ	Ḫ	Ṽ Ḫ	Ḫ
	$Ṃ_3$	Ṣ	Ṽ Ḫ	ṼḸ	Ṽ Ḫ
	$Ṃ_4$	Ḫ	Ṣ	ṼḸ	ṼḸ
	$Ṃ_5$	Ṽ Ḫ	ṼḸ	Ḹ	Ḹ
	$Ṃ_6$	ṼḸ	Ḹ	Ṣ	Ṣ
$Ƈ_2$= ROM	$Ṃ_1$	Ḹ	Ṣ	Ḫ	Ḫ
	$Ṃ_2$	Ṣ	Ḫ	Ṽ Ḫ	Ṽ Ḫ
	$Ṃ_3$	Ḫ	Ṽ Ḫ	ṼḸ	Ṣ
	$Ṃ_4$	Ṽ Ḫ	Ṣ	Ḹ	Ḫ
	$Ṃ_5$	ṼḸ	Ḫ	Ṣ	Ṽ Ḫ
	$Ṃ_6$	Ḹ	Ṽ Ḫ	Ḫ	Ṣ
$Ƈ_3$= PROCESSOR	$Ṃ_1$	Ṣ	ṼḸ	Ṽ Ḫ	Ḫ
	$Ṃ_2$	Ḫ	Ḹ	Ṣ	Ṽ Ḫ
	$Ṃ_3$	Ṽ Ḫ	Ṣ	Ḫ	ṼḸ
	$Ṃ_4$	Ṣ	Ḫ	Ṽ Ḫ	Ḹ
	$Ṃ_5$	Ḫ	Ṽ Ḫ	Ḹ	Ṣ
	$Ṃ_6$	Ṽ Ḫ	Ṣ	Ḫ	ṼḸ
$Ƈ_4$= CAMERA	$Ṃ_1$	ṼḸ	Ḫ	Ṽ Ḫ	Ḹ
	$Ṃ_2$	Ḹ	Ṽ Ḫ	ṼḸ	Ḫ
	$Ṃ_3$	Ṣ	Ḫ		Ṽ Ḫ
	$Ṃ_4$	Ḫ	Ṽ Ḫ	ṼḸ	Ḹ
	$Ṃ_5$	Ṽ Ḫ	ṼḸ	Ḹ	Ḫ
	$Ṃ_6$	ṼḸ	Ṣ	Ḹ	Ṣ
$Ƈ_5$= DISPLAY SIZE	$Ṃ_1$	Ḹ	Ḫ	Ḫ	Ḫ
	$Ṃ_2$	Ṣ	Ṽ Ḫ	Ḹ	Ṽ Ḫ
	$Ṃ_3$	Ḫ	Ṣ	Ṽ Ḫ	ṼḸ
	$Ṃ_4$	Ṽ Ḫ	Ḫ	Ḹ	Ṽ Ḫ
	$Ṃ_5$	Ṣ	Ṽ Ḫ	Ḫ	ṼḸ
	$Ṃ_6$	Ṽ Ḫ	ṼḸ	Ḹ	Ḫ

Step 4: Substitution of Neutrosophic Numbers (NNs) to each linguistic variable.

Table3: Assign neutrosophic number to each linguistic value from table 1.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
M_1	(0.1, 0.3,0.7)	(1,0.1,0.2)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.1, 0.3,0.7)	(0.7,0.3,0.4)
M_2	(0.3,0.5,0.6)	(0.5,0.5,0.5)	(0.1, 0.3,0.7)	(1,0.1,0.2)	(0.7,0.3,0.4)	(0.3,0.5,0.6)	(0.1, 0.3,0.7)
M_3	(0.5,0.5,0.5)	(0.1, 0.3,0.7)	(0.3,0.5,0.6)	(1,0.1,0.2)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(1,0.1,0.2)
M_4	(0.7,0.3,0.4)	(1,0.1,0.2)	(0.5,0.5,0.5)	(0.3,0.5,0.6)	(1,0.1,0.2)	(0.7,0.3,0.4)	(0.1, 0.3,0.7)
M_5	(1,0.1,0.2)	(0.3,0.5,0.6)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.1, 0.3,0.7)	(1,0.1,0.2)	(0.5,0.5,0.5)
M_6	(0.5,0.5,0.5)	(0.1, 0.3,0.7)	(1,0.1,0.2)	(0.7,0.3,0.4)	(0.1, 0.3,0.7)	(0.5,0.5,0.5)	(0.7,0.3,0.4)

Step 5: Conversion of fuzzy neutrosophic numbers NNs of step 4, into fuzzy numbers by using accuracy function.

$$\mathrm{A(F)} = \{\, x = \frac{[T_x+I_x+F_x]}{3} \,\}$$

Table: 4 After applied accuracy function the obtain result converted into fuzzy value

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
M_1	0.367	0.433	0.467	0.467	0.5	0.367	0.467
M_2	0.467	0.5	0.367	0.433	0.467	0.467	0.367
M_3	0.5	0.367	0.467	0.433	0.467	0.5	0.433
M_4	0.467	0.433	0.5	0.467	0.433	0.467	0.367
M_5	0.433	0.467	0.467	0.5	0.367	0.433	0.5
M_6	0.5	0.367	0.433	0.467	0.367	0.5	0.467

Step 6: Now we apply algorithm of TOPSIS to obtain relative closeness.

Table 5: Normalized decision matrices

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
M_1	0.327	0.410	0.422	0.413	0.468	0.327	0.437
M_2	0.416	0.474	0.332	0.383	0.437	0.416	0.343
M_3	0.446	0.348	0.422	0.383	0.437	0.446	0.405
M_4	0.416	0.410	0.452	0.413	0.405	0.416	0.343
M_5	0.386	0.443	0.422	0.442	0.343	0.386	0.468
M_6	0.446	0.348	0.391	0.413	0.343	0.446	0.437

Step 6.1: Calculation of weighted normalized matrix

Table6: Weighted normalized decision matrices

weight	0.2	0.3	0.17	0.02	0.25	0.05	0.01
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
M_1	0.0654	0.123	0.07174	0.00826	0.117	0.01635	0.00437
M_2	0.0832	0.1422	0.05644	0.00766	0.10925	0.0208	0.00343
M_3	0.0892	0.1044	0.07174	0.00766	0.10925	0.0223	0.00405
M_4	0.0832	0.123	0.07684	0.00826	0.1015	0.0208	0.00343
M_5	0.0772	0.1329	0.07174	0.00884	0.08575	0.0193	0.00468
M_6	0.0892	0.1044	0.06647	0.00826	0.08575	0.0223	0.00437

Step 6.2: Calculation of the ideal best and ideal worst value,

v_j^+ =Indicates the ideal (best)

v_j^- = Indicates the ideal (worst)

Table 7: Ideal worst and Ideal best values

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
M_1	0.0654	0.123	0.07174	0.00826	0.117	0.01635	0.00437
M_2	0.0832	0.1422	0.05644	0.00766	0.10925	0.0208	0.00343
M_3	0.0892	0.1044	0.07174	0.00766	0.10925	0.0223	0.00405
M_4	0.0832	0.123	0.07684	0.00826	0.1015	0.0208	0.00343
M_5	0.0772	0.1329	0.07174	0.00884	0.08575	0.0193	0.00468
M_6	0.0892	0.1044	0.06647	0.00826	0.08575	0.0223	0.00437
v_j^+	0.0892	0.1422	0.07684	0.0084	0.117	0.0223	0.00343
v_j^-	0.0654	0.1044	0.05644	0.00766	0.08575	0.01635	0.00437

Step 6.3: Calculation of rank.

$$p_i = \frac{s_{ij}^-}{s_{ij}^+ + s_{ij}^-}$$

Table 8: Calculation of rank by relative closeness

	s_j^+	s_j^-	$s_{ij}^+ + s_{ij}^-$	p	Rank
M_1	0.0316	0.0400	0.0716	0.5587	3
M_2	0.0245	0.0843	0.1088	0. 3402	6
M_3	0.0400	0.0374	0.0774	0.4832	4
M_4	0.0249	0.0374	0.0623	0.6003	2
M_5	0.0671	0.0346	0.1017	0.7748	1
M_6	0.0500	0.0271	0.0771	0.3515	5

Step 7: Calculation of rank and discussion.

4. Result Discussion

Firstly, the generalized neutrosophic TOPSIS approach is used to simplify mobile selection MCDM problem. In this calculation, the ranking of each mobile with respect to each criterion is represented below in Table 8 and Figure 2. To test the validity and the implementation of the technique proposed by Saqlain *et. al.* [17], in neutrosophic soft set environment and multi-criteria decision making, mobile selection problem is considered. Result shows that generalized neutrosophic TOPSIS along with proposed algorithm can be used to find best alternative.

Secondly, results are compared with [10], in which fuzzy multi-criteria group decision making approach was used by considering same alternative and attributes. Graphical and tabular comparison is presented in Table 8 and Figure 2, which shows that under Generalized TOPSIS and Fuzzy TOPSIS M_5 and M_5 are best alternative whereas, M_2 and M_3 is the worst selection respectively.

If we compare the results of Generalized fuzzy TOPSIS and Fuzzy TOPSIS M_1, M_4, M_5 has same raking whereas, M_2, M_3, M_6.

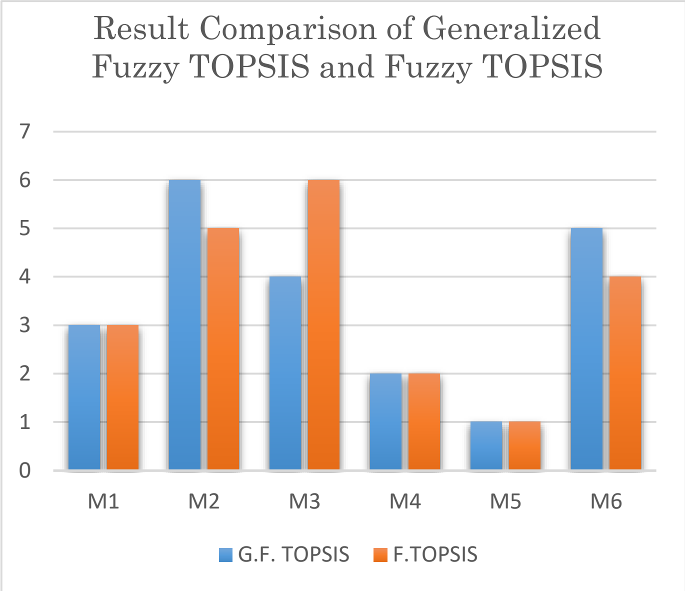

Figure 2: Ranking comparison of alternatives

Table 9: Ranking comparison of alternatives using G.F. TOPSIS and F. TOPSIS

Strategy	Generalized Fuzzy TOPSIS-Result Ranking	Fuzzy TOPSIS Ranking
M_1	3	3
M_2	6	5
M_3	4	6
M_4	2	2
M_5	1	1
M_6	5	4

5. Conclusions

In MCDM problems, TOPSIS is widely used to find the best alternative, whereas, due to the vague and imprecise information in fuzzy environment, ranking of alternatives may not be accurate. Thus, neutrosophic soft set environment plays a vital role in selection problem. In this article, firstly, an algorithm is proposed based on accuracy function under neutrosophic soft set environment and to check the validity of the proposed technique in this environment, mobile selection problem is considered. Secondly, results are compared with same problem under FMCGDM [10] environment. However, the article may open a new avenue of research in competitive Neutrosophic decision-making arena. Thus, this proposed technique can be used in decision-makings such as supplier selection, personal selection in academia and many other areas of management system.

Conflicts of Interest

The authors declare no conflict of interest.

Reference:

1. M. Abdel-Basset, M. Mohamed, Y. Zhou, I. Hezam, (2017). Multi-criteria group decision making based on the neutrosophic analytic hierarchy process. Journal of Intelligent & Fuzzy Systems, 33(6): 4055-4066.
2. Abdel-Basset, M., M. Mohamed, (2018). The role of single-valued neutrosophic sets and rough sets in the smart city: imperfect and incomplete information systems. Measurement, 124: 47-55.
3. A. Adeel, M. Akram and Ali N. A. Koam, Group Decision-Making Based on m-Polar Fuzzy Linguistic TOPSIS Method, Symmetry 11, No. 735 (2019) 1-20.
4. M. Akram and M. Arshad, A Novel Trapezoidal Bipolar Fuzzy TOPSIS Method for Group Decision-Making, Group Decision and Negotiation (2018), https://doi.org/10.1007/s10726-018-9606-6.
5. F. E. Boran, S. Genc, M. Kurt and D. Akay, A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method, Expert Systems with Applications 36, No. 8 (2009) 11363-11368.
6. Büyüközkan, G., and Güleryüz, S. (2016). Multi criteria group decision making approach for smart phone selection using intuitionistic fuzzy TOPSIS. International Journal of Computational Intelligence Systems, 9(4): 709-725.
7. S. Eraslan and F. Karaaslan, A group decision making method based on topsis under fuzzy soft environment, Journal of New Theory 3, No. (2015) 30-40.
8. Heeks, Richard (2008). Meet Marty Cooper – the inventor of the mobile phone, BBC. 41 (6): 26–33.
9. Hwang, C.L., Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag
10. Saqlain. M., Jafar. N. and Riffat. A., Smart phone selection by consumers' in Pakistan: FMCGDM fuzzy multiple criteria group decision making approach, *Gomal University Journal of Research*, 34(1): 27-31 (2018).
11. Kumar and H. Garg, TOPSIS method based on the connection number of set pair analysis under interval valued intuitionistic fuzzy set environment Computational and Applied Mathematics 37, No. 2 (2018), 1319-1329.
12. P. K. Maji, Neutrosophic soft set, Annals of Fuzzy Mathematics and Informatics 5, No. 1 (2013) 157-168.
13. X. D. Peng and J. Dai, Approaches to single-valued neutrosophic MADM based on MABAC, TOPSIS and new similarity measure with score function, Neural Computing and Applications 29, No. 10 (2018) 939-954.
14. M. Riaz and K. Naeem, Measurable Soft Mappings, Punjab Univ. j. math. 48, No. 2 (2016) 19-34.
15. M. Riaz, K. Naeem and M. O. Ahmad, Novel Concepts of Soft Sets with Applications, Annals of Fuzzy Mathematics and Informatics 13(2) (2017) 239-251.
16. M. Saqlain, N. Jafar, M. Rashid and A. Shahzad, Prediction of Cricket World Cup 2019 by TOPSIS Technique of MCDM-A Mathematical Analysis, International Journal of Scientific & Engineering Research, 10(2): 789-792, (2019).
17. Saqlain, M., Saeed, M., Ahmad, R. and Smarandache, F. (2019). Generalization of TOPSIS for Neutrosophic Hypersoft set using Accuracy Function and its Application. Neutrosophic Sets and Systems, 27: 131-137.
18. G. Selvachandran and X. D. Peng, A modified TOPSIS method based on vague parameterized vague soft sets and its application to supplier selection problems, Neural Computing and Applications (2018) 1-16.
19. G. Selvachandran and X. D. Peng, (2018). A modified TOPSIS method based on vague parameterized vague soft sets and its application to supplier selection problems, Neural Computing and Applications, 1-16.
20. F. Smarandache, (1998). Neutrosophy. Neutrosophic probability, set, and logic. ProQuest Information & Learning, Ann Arbor, Michigan, USA.
21. Z. Xu and X. Zhang, Hesitant fuzzy multi-attribute decision-making based on TOPSIS with incomplete weight information, Knowledge-Based Systems 52, (2013) 53-64.
22. Yoon, K. (1987). A reconciliation among discrete compromise situations. Journal of the Operational Research Society. 38 (3): 277–286.
23. L. A. Zadeh, (1965). Fuzzy sets, Information and Control, 8: 338-353.

24. X. Zhang and Z. Xu, Extension of TOPSIS to multiple criteria decision making with Pythagorean fuzzy sets, International Journal of Intelligent Systems 29, (2014) 1061-1078.
25. M. Riaz and M. R. Hashmi, Linear Diophantine Fuzzy Set and its Applications towards Multi-Attribute Decision Making Problems, Journal of Intelligent and Fuzzy Systems, 37(4) (2019), 5417-5439. DOI:10.3233/JIFS-190550.
26. M. Riaz and S. T. Tehrim, Bipolar Fuzzy Soft Mappings with Application to Bipolar Disorders, International Journal of Biomathematics, 12(7) (2019), 1-31. Doi.org/10.1142/S1793524519500803.
27. K. Naeem, M. Riaz, X.D. Peng and D. Afzal, Pythagorean Fuzzy Soft MCGDM Methods Based on TOPSIS, VIKOR and Aggregation Operators, Journal of Intelligent and Fuzzy Systems, (2019) DOI:10.3233/JIFS- 190905.
28. K. Naeem, M. Riaz, and Deeba Afzal, Pythagorean m-polar Fuzzy Sets and TOPSIS method for the Selection of Advertisement Mode, Journal of Intelligent & Fuzzy Systems, 37(6)(2019), 8441-8458. DOI: 10.3233/JIFS-191087.
29. S. T. Tehrim and M. Riaz, A novel extension of TOPSIS to MCGDM with Bipolar Neutrosophic soft topology, Journal of Intelligent and Fuzzy Systems, 37(4)(2019), 5531-5549. DOI:10.3233/JIFS-190668.
30. M. Riaz, B. Davvaz, A. Firdous and A. Fakhar, Novel Concepts of Soft Rough Set Topology with Applications, Journal of Intelligent & Fuzzy Systems 36(4) (2019) 3579-3590. DOI:10.3233/JIFS-181648.
31. Abdel-Baset, M., Chang, V., & Gamal, A. (2019). Evaluation of the green supply chain management practices: A novel neutrosophic approach. Computers in Industry, 108, 210-220.
32. Abdel-Basset, M., Saleh, M., Gamal, A., & Smarandache, F. (2019). An approach of TOPSIS technique for developing supplier selection with group decision making under type-2 neutrosophic number. Applied Soft Computing, 77, 438-452.
33. Abdel-Basset, M., Manogaran, G., Gamal, A., & Smarandache, F. (2019). A group decision making framework based on neutrosophic TOPSIS approach for smart medical device selection. Journal of medical systems, 43(2), 38.
34. Abdel-Basset, M., Atef, A., & Smarandache, F. (2019). A hybrid Neutrosophic multiple criteria group decision making approach for project selection. Cognitive Systems Research, 57, 216-227.
35. Abdel-Basset, Mohamed, Mumtaz Ali, and Asma Atef. "Resource levelling problem in construction projects under neutrosophic environment." The Journal of Supercomputing (2019): 1-25.
36. Saqlain M, Sana M, Jafar N, Saeed. M, Said. B, Single and Multi-valued Neutrosophic Hypersoft set and Tangent Similarity Measure of Single valued Neutrosophic Hypersoft Sets, *Neutrosophic Sets and Systems (NSS),* 32: (2020).
37. S. Pramanik, P. P. Dey and B. C. Giri, TOPSIS for single valued neutrosophic soft expert set based multi-attribute decision making problems, *Neutrosophic Sets and Systems*, 10, (2015), 88-95.
38. Saqlain. M, Jafar.N. M, and Muniba. K, Change in The Layers of Earth in Term of Fractional Derivative: A Study, *Gomal University Journal of Research*, 34(2): 27-31 (2018).
39. Riaz.M., Saeed.M. Saqlain.M. and Jafar.N. Impact of Water Hardness in Instinctive Laundry System based on Fuzzy Logic Controller, Punjab *University Journal of Mathematics*, 51(4) (2018) 73-84.
40. Riaz. M., Saqlain. M. and Saeed. M. (2019). Application of Generalized Fuzzy TOPSIS in Decision Making for Neutrosophic Soft set to Predict the Champion of FIFA 2018: A Mathematical Analysis, *Punjab University Journal of Mathematics*, 51(8): 111-126.
41. Saqlain M, Sana M, Jafar N, Saeed. M, Smarandache, F., Aggregate Operators of Neutrosophic Hypersoft Sets, *Neutrosophic Sets and Systems (NSS),* 32: (2020).
42. İ. Deli and S. Broumi, Neutrosophic Soft Matrices and NSM-decision Making, Journal of Intelligent and Fuzzy Systems, 28 (5) (2015) 2233–2241.
43. I. Deli and N. Çağman, Intuitionistic fuzzy parameterized soft set theory and its decision making, Applied Soft Computing 28 (2015) 109–113.
44. İ. Deli and S. Broumi, Neutrosophic soft relations and some properties, Annals of Fuzzy Mathematics and Informatics 9(1) (2015) 169–182.
45. İ. Deli, npn-Soft Sets Theory and Applications, Annals of Fuzzy Mathematics and Informatics, 10/6 (2015) 847–862.

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