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Contributions of Selected Indian Researchers to Multi Attribute Decision Making in Neutrosophic Environment: An Overview

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Abstract Multi-attribute decision making (MADM) is a mathematical tool to solve decision problems involving conflicting attributes. With the increasing complexity, uncertainty of objective things and the neutrosophic nature of human thought, more and more attention has been paid to the investigation on multi attribute decision making in neutrosophic environment, and convincing research results have been reported in the literature. While modern algebra and number theory have well documented and established roots deep into India's ancient scholarly history, the understanding of the springing up of neutrosophics, specifically neutrosophic decision making, demands a closer inquiry. The objective of the study is to present a brief review of the pioneering contributions of personalities as diverse as those of P. P. Dey, K. Mondal, P. Biswas, D. Banerjee, S. Dalapati, P. K. Maji, A. Mukherjee, T. K. Roy, B. C. Giri, H. Garg, S. Bhattacharya. A survey of various concepts, issues, etc. related to neutrosophic decision making is discussed. New research direction of neutrosophic decision making is also provided.

Keywords: Bipolar neutrosophic sets, VIKOR method, multi attribute group decision making.

1 Introduction

Every human being has to make decision in every sphere of his/her life. So decision making should be pragmatic and elegant. Decision making involves multi attributes. Multi attribute decision making (MADM) refers to making selections among some courses of actions in the presence of multiple, usually conflicting attributes. MADM is the most well-known branch of decision making. To solve a MADM one needs to employ sorting and ranking (see Figure 1).

It has been widely recognized that most real world decisions take place in uncertain environment where crisp values cannot capture the reflection of the complexity, indeterminacy, inconsistency and uncertainty of the problem.

To deal with crisp MADM problem [1], classical set or crisp set [2] is employed. The classical MADM generally assumes that all the criteria and their respective weights are expressed in terms of crisp numbers and, thus, the rating and the ranking of the alternatives are determined. However, practical decision making problem involves imprecision or vagueness. Imprecision or vagueness may occur from different sources such as unquantifiable information, incomplete information, non-obtainable information, and partial ignorance.

To tackle uncertainty, Zadeh [3] proposed the fuzzy set by introducing membership degree of an element. Different strategies [4-9] have been proposed for dealing with MADM in fuzzy environment. In fuzzy set, non-membership membership function is the complement of membership function. However, non-membership function may be independent in real situation. Sensing this, Atanassov [10] proposed intuitionistic fuzzy set by incorporating non-membership as an independent component. Many MADM strategies [11-14] in intuitionistic fuzzy environment have been studied in the literature. Deschrijver and Kerre [15] proved that intuitionistic fuzzy set is equivalent to interval valued fuzzy set [16], an extension of fuzzy set.

In real world decision making often involves incomplete, indeterminate and inconsistent information. Fuzzy set and intuitionistic fuzzy set cannot deal with the situation where indeterminacy component is independent of truth and falsity components. To deal with this situation, Smarandache [17] defined neutrosophic set. In 2005, Wang et al. [18] defined interval neutrosophic set. In 2010, Wang et al. [19] introduced the single valued neutrosophic set (SVNS) as a sub class of neutrosophic set. SVNS have caught much attention of the researchers. SVNS have been applied in many areas such as conflict resolution [20], decision making [21-30], image processing [31-33], medical diagnosis [34], social problem [35-36], and so on. In 2013, a new journal, "Neutrosophic Sets and Systems" came into being to propagate neutrosophic study, which can be seen in the journal website, namely, http://fs.gallup.unm.edu/nss. By hybridizing the concept of neutrosophic sets or SVNSs with the various established sets, several neutrosophic hybrid sets have been introduced in the literature such as neutrosophic soft sets [37], neutrosophic soft expert set [38], single valued neutrosophic hesitant fuzzy sets [39], interval neutrosophic hesitant sets [40], interval neutrosophic linguistic sets [41], rough neutrosophic set [42, 43], interval rough neutrosophic set [44], bipolar neutrosophic set [45], bipolar rough neutrosophic set [46], tri-complex rough neutrosophic set [47], hyper complex rough neutrosophic set [48], neutrosophic refined set [49], bipolar neutrosophic refined sets [50], neutrosophic cubic set [51], etc.

So many new areas of decision making in neutrosophic hybrid environment began to emerge. Young researchers demonstrate great interest to conduct research on decision making in neutrosophic as well as neutrosophic hybrid environment. According to Pramanik [52], the concept of neutrosophic set was initially ignored, criticized by many [53, 54], while it was supported only by a very few, mostly young, unknown, and uninfluential researchers. As we see Smarandache [55, 55, 56, 57] leads from the front and makes the paths for research by publishing new books, journal articles, monographs, etc. In India, W. B. V. Kandasamy [58, 59] did many research works on neutrosophic algebra, neutrosophic cognitive maps, etc. She is a well-known researcher in neutrosophic study. Pramanik and Chackrabarti [36] and Pramanik [60, 61] did some work on neutrosophic related problems. Initially, publishing neutrosophic research paper in a recognized journal was a hard work. Pramanik and his colleagues were frustrated by the rejection of several neutrosophic research papers without any valid reasons. After the publication of the International Journal namely, "Neutrosophic Sets and Systems" Pramanik and his colleagues explored the area of decision making in neutrosophic environment to establish their research work.

In 2016, to present history of neutrosophic theory and applications, Smarandache [62] published an edited volume comprising of the short biography and research work of neutrosophic researchers. "*The Encyclopedia of Neutrosophic Researchers*" includes the researchers, who published neutrosophic papers, books, or defended neutrosophic master theses or Ph. D. dissertations. It encourages researchers to conduct study in neutrosophic environment. The fields of neutrosophics have been extended and applied in various fields, such as artificial intelligence, data mining, soft computing, image processing, computational modelling, robotics, medical diagnosis, biomedical engineering, investment problems, economic forecasting, social science, humanistic and practical achievements, and decision making. Decision making in incomplete / indeterminate / inconsistent information systems has been deeply studied by the Indian researchers. New trends in neutrosophic theory and applications can be found in [62-67].

Considering the potentiality of SVNS and its various extensions and their importance of decision making, we feel a sense of commitment to survey the contribution of Indian mathematicians to multi attribute decision making. The venture is exclusively new and therefore it may be considered as an exploratory study.

Research gap:

Survey of new research in MADM conducted by the Indian researchers.

Statement of the problem:

Contributions of selected Indian researchers to multi-attribute decision making in neutrosophic environment: An overview.

Motivation:

The above-mentioned analysis describes the motivation behind the present study.

Objectives of the study

The objective of the study is:

- To present a brief review of the pioneering contributions of personalities as diverse as those of Dr. Partha Pratim Dey, Dr. Pranab Biswas, Dr. Durga Banerjee, Mr. Kalyan Mondal, Shyamal Dalapati, Dr. P. K. Maji, Prof. T. K. Roy, Prof. B. C. Giri, Prof. Anjan Mukherjee, Dr. Harish Garg and Dr. Sukanto Bhattacharya.

Rest of the paper is organized as follows: In section 2, we review some basic concepts related to neutrosophic set. Section 3 presents the contribution of the selected Indian researchers. Section 4 presents conclusion and future scope of research.

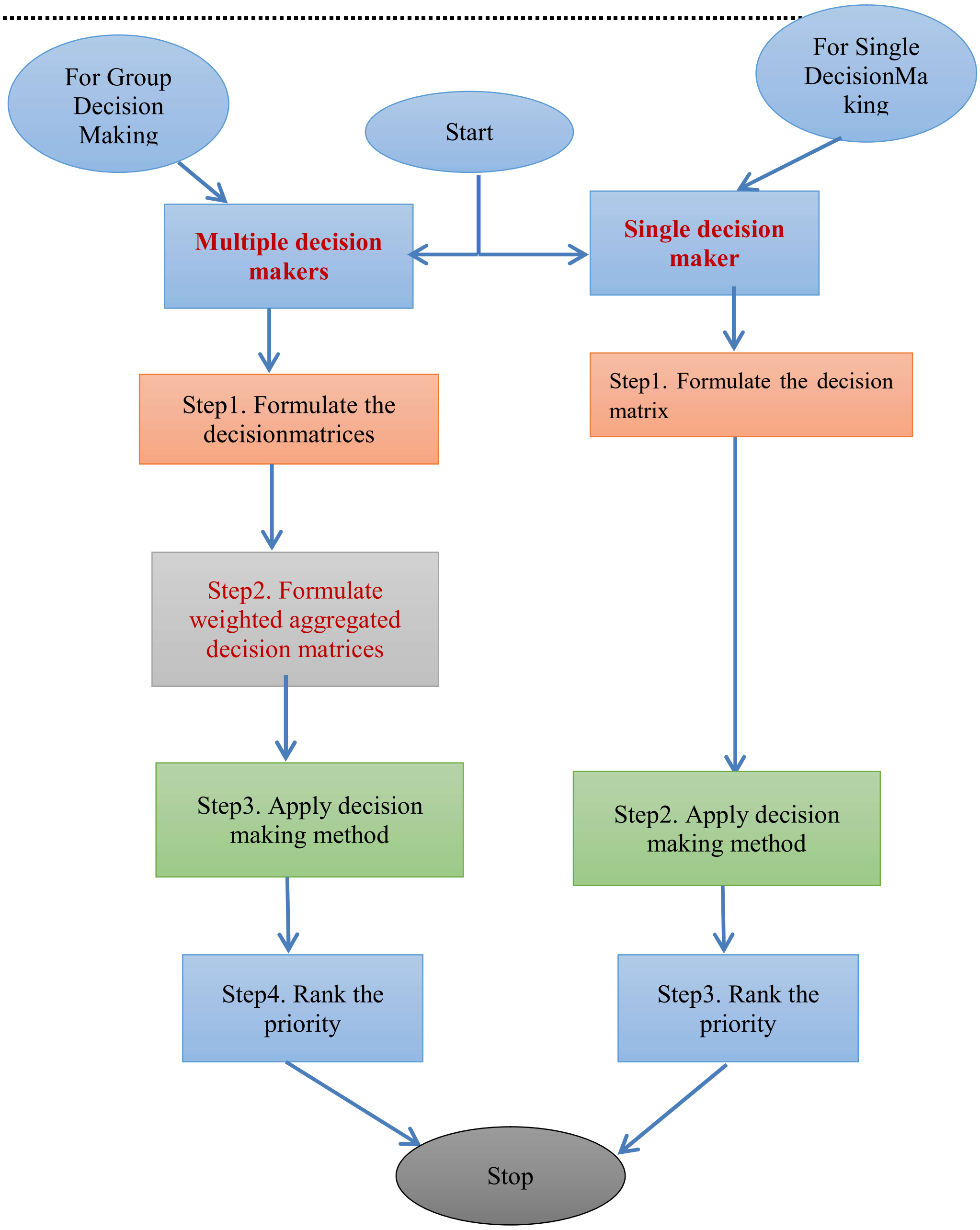

Figure 1. Decision making steps

2. Preliminaries

In this section we recall some basic definitions related to this topic.

Definition.2.1 Neutrosophic Set

Let X be the universe. A neutrosophic set (NS) [17] P in X is characterized by a truth membership function T_P, an indeterminacy membership function I_P and a falsity membership function F_P where T_P, I_P and F_P are real standard or non-standard subset of $]^-0,1^+[$. It can be defined as:

$P=\{<x,(T_P(x),I_P(x),F_P(x))>:x\in X, T_P,I_P,F_P \in]^-0,1^+[\}$

There is no restriction on the sum of $T_P(x),I_P(x)$ and $F_P(x)$ and so $0^- \le T_P(x)+I_P(x)+F_P(x) \le 3^+$.

Definition 2.2 Single valued neutrosophic set

Let X be a space of points (objects) with generic element in X denoted by x. A single valued neutrosophic set [19] P is characterized by a truth-membership function $T_P(x)$, an indeterminacy-membership function $I_P(x)$, and a falsity-membership function $F_P(x)$. For each point x in X, $T_P(x),I_P(x),F_P(x) \in [0, 1]$. A SVNS A can be written as:

$A = \{<x: T_P(x),I_P(x),F_P(x)>, x \in X\}$.

Definition 2.3 Interval valued neutrosophic set

Let X be a space of points (objects) with generic elements in X denoted by x. An interval valued neutrosophic set [18] P is characterized by an interval truth-membership function $T_P(x)=[T_P^L, T_P^U]$, an interval indeterminacy-membership function $I_P(x)=[I_P^L, I_P^U]$, and an interval falsity-membership function $F_P(x)=[F_P^L, F_P^U]$. For each point $x\in X$, $T_P(x)$, $I_P(x)$, $F_P(x) \subset [0, 1]$. An IVNS P can be written as:

$P = \{< x: T_P(x),I_P(x),F_P(x)> x \in X\}$.

Definition 2.4: Bipolar neutrosophic set

A bipolar neutrosophic set [45] P in X is defined as an object of the form $P=\{<x, T^m(x), I^m(x), F^m(x), T^n(x), I^n(x), F^n(x) >: x \in X\}$, where $T^m, I^m, F^m: X \to [1, 0]$ and $T^n, I^n, F^n: X \to [-1, 0]$. The positive membership degree $T^m(x)$, $I^m(x)$, $F^m(x)$ denotes respectively the truth membership, indeterminate membership and false membership degree of an element $\in X$ corresponding to a bipolar neutrosophic set P and the negative membership degree $T^n(x)$, $I^n(x)$, $F^n(x)$ denotes respectively the truth membership, indeterminate membership and false membership degree of an element $x \in X$ to some implicit counter-property corresponding to a bipolar neutrosophic set P.

Definition 2.5: Neutrosophich hesitant fuzzy set

Let X be a fixed set, a neutrosophic hesitantfuzzy set [39] (NHFS) on X is defined as:

$M=\{<x,T(x),I(x),F(x)>|x \in X\}$, where $T(x) = \{\alpha | \alpha \in T(x)\}$, $I(x) = \{\beta | \beta \in I(x)\}$ and $F(x) = \{\gamma | \gamma \in F(x)\}$ are the three sets of some different values in the interval [0, 1], which represent the possible truth-membership hesitant degree, indeterminacy-membership hesitant degree, and falsity-membership hesitant degree of the element $x\in X$ to the set M, and satisfies the following conditions:

$\alpha\in[0,1], \beta\in[0,1], \gamma\in[0,1]$ and $0 \le sup\, \alpha^+ + sup\beta^+ + sup\gamma^+ \le 3$ where $\alpha^+ = \cup_{\alpha\in T(x)} max\{\alpha\}$, $\beta^+ = \cup_{\beta\in I(x)} max\beta$ and $\gamma^+ = \cup_{\gamma\in F(x)} max\{\gamma\}$ for $x \in X$.

The $triplet\; m = \{T(x), I(x), F(x)\}$ is called a neutrosophic hesitant fuzzy element (NHFE) which is the basic unit of the NHFS and is denoted by the symbol $m=\{T, I, F\}$.

Definition 2.6: Interval neutrosophic hesitant fuzzy set

Let X be a nonempty fixed set, an Interval neutrosophic hesitant fuzzy set [67] on X is defined as :

$P = \{\langle x, T(x), I(x), F(x)\rangle | x \in X\}$.

Here $T(x)$, $I(x)$ and $F(x)$ are sets of some different interval values in [0, 1], which denotes respectively the possible truth-membership hesitant degree, indeterminacy-membership hesitant degree, and falsity-membership hesitant degree of the element $x \in \Omega$ to the set P. Then, $T(x)=\{\tilde{\alpha} | \tilde{\alpha} \in T(x)\}$, $where\; \tilde{\alpha} = [\tilde{\alpha}^L, \tilde{\alpha}^U]$ is an interval number; $\tilde{\alpha}^L = inf\, \tilde{\alpha}$ and $\tilde{\alpha}^U = sup\tilde{\alpha}$ represents the lower and upper limits of $\tilde{\alpha}$, respectively; $I(x) = \{\tilde{\beta} | \tilde{\beta} \in I(x)\}$, $where\; \tilde{\beta} = [\tilde{\beta}^L, \tilde{\beta}^U]$ is an interval number; $\tilde{\beta}^L = \inf\tilde{\beta}$ and $\tilde{\beta}^U = \sup\tilde{\beta}$ represents the lower and upper limits of $\tilde{\beta}$, respectively; $F(x)= \{\tilde{\gamma} | \tilde{\gamma} \in F(x)$, where $\tilde{\gamma} = [\tilde{\gamma}^L, \tilde{\gamma}^U]$ is an intervalnumber; $\tilde{\gamma}^L = inf\tilde{\gamma}$ and, $\tilde{\gamma}^U = sup\tilde{\gamma}$ represents the lower and upper limits of $\tilde{\gamma}$, respectively and satisfied the condition

$0 \le sup\tilde{\alpha}^+ + sup\tilde{\beta}^+ + sup\tilde{\gamma}^+ \le 3$

where $\tilde{\alpha}^+ = \cup_{\tilde{\alpha}\in T(x)} max\{\tilde{\alpha}\}$, $\tilde{\beta}^+ = \cup_{\tilde{\beta}\in I(x)} max\{\tilde{\beta}\}$ $and\; \tilde{\gamma}^+ = \cup_{\tilde{\gamma}\in F(x)} max\{\tilde{\gamma}\} for x \in X$.

The triplet $\tilde{p} = \{T(x), I(x), F(x)\}$ is called an interval neutrosophic hesitant fuzzy element or simply INHFE, which is denoted by the symbol $\widetilde{p} = \{T, I, F\}$.

Definition 2.7 Triangular fuzzy neutrosophic sets

Let X be the finite universe and F [0, 1] be the set of all triangular fuzzy numbers on [0, 1]. A triangular fuzzy neutrosophicset (TFNS) [68] P *with* $T_P(x)$:$X\to F[0,1]$,I_P:$X\to [0,1]$ and F_P:$X\to$ in X is defined as:

$P=\{<x:T_P(x),I_P(x),F_p(x)>,x\epsilon X\}$,

where $T_P(x):X\to F[0,1]$, $I_P:X\to[0,1]$ and $F_P:X\to[0,1]$. The triangular fuzzy numbers $T_P(x) =(T_P^1, T_P^2, T_P^3)$, $I_P(x)=(I_P^1, I_P^2, I_P^3)$ and $F_P(x)=(F_P^1, F_P^2, F_P^3)$, respectively, denotesrespectively the possible truth-membership, indeterminacy-membership and a falsity-membership degree of x in P and for every $x \in X$ $0\leq T_P^3(x) + I_P^3(x) + F_P^3(x) \leq 3$.

The triangular fuzzy neutrosophic value (TFNV)P is symbolized by $<(l,m,n),(p,q,r),(u,v,w)>$where,$(T_P^1(x), T_P^2(x), T_P^3(x)) = (l,m,n)$,$(I_P^1(x), I_P^2(x), I_P^3(x)) = (p,q,r)$ and $(F_p^1(x), F_p^2(x), F_p^3(x))$ = (u,v,w).

Definition2.8Neutrosophic soft set

Let V be an initial universe set and E be a set of parameters. Consider $A \subset E$. Let $P(V)$ denote the set of all neutrosophic sets of V. The collection (F, A) is termed to be the soft neutrosophic set [37] over V, where F is a mapping given by $F : A \to P(V)$.

Definition 2.9 Neutrosophic cubic set

Let U be the space of points with generic element in U denoted by $u \in U$. A neutrosophic cubic set [51]in U defined as $\ddot{N} = \{< u, A(u), \lambda(u) >: u \in U\}$ in which $A(u)$ is the interval valued neutrosophic set and $\lambda(u)$ is the neutrosophic set in U. A neutrosophic cubic set in U denoted by $\ddot{N} = <A, \lambda>$. We use $C\ddot{N}(U)$ as a notation which implies that collection of all neutrosophic cubic sets in U.

Definition 2.10 Rough Neutrosophic Sets

Let X be a non empty set and R be an equivalence relation on X . Let P be a neutrosophic set in Y with the membership function T_P, indeterminacy function I_P and non-membership function F_P. The lower and the upper approximations of P in the approximation (X, R) denoted by $\underline{L}(P)$ *and* $\overline{L}(P)$ are respectively defined as follows:

$$\underline{L}(P)=\left\langle <x,T_{\underline{L}(P)}(x),I_{\underline{L}(P)}(x),F_{\underline{L}(P)}(x)> / \, y\in[x]_R, x\in X\right\rangle,$$

$$\overline{L}(P)=\left\langle <x,T_{\overline{L}(P)}(x),I_{\overline{L}(P)}(x),F_{\overline{L}(P)}(x)> / \, y\in[x]_R, x\in X\right\rangle,$$

$T_{\underline{L}(P)}(x)=\wedge_{y}\in[x]_R\, T_P(y)$,

$I_{\underline{L}(P)}(x)=\vee_{y}\in[x]_R\, I_P(y)$,

$F_{\underline{L}(P)}(x)=\vee_{y}\in[x]_R\, F_P(y)$,

$T_{\overline{L}(P)}(x)=\vee_{y}\in[x]_R\, T_P(y)$,

$I_{\overline{L}(P)}(x)=\wedge_{y}\in[x]_R\, I_P(y)$,

$F_{\overline{L}(P)}(x)=\wedge_{y}\in[x]_R\, F_P(y)$

So, $0\leq \sup T_{\underline{L}(P)}(x) + \sup I_{\underline{L}(P)}(x) + \sup F_{\underline{L}(P)}(x) \leq 3$.

$0\leq \sup T_{\overline{L}(P)}(x) + \sup I_{\overline{L}(P)}(x) + \sup F_{\overline{L}(P)}(x) \leq 3$.

Here $\vee$ and $\wedge$ denotes "max" and "min'' operators respectively. $T_P(y)$, $I_P(y)$ and $F_P(y)$ are the membership, indeterminacy and non-membership function of y with respect to P and also $\underline{L}(P)$ and $\overline{L}(P)$ are two neutrosophic sets in X.

Therefore, NS mapping $\underline{L}$, $\overline{L}$:$L(X) \to L(X)$ are, respectively, referred to as the lower and the upper rough NS approximation operators, and the pair $(\underline{L}(P), \overline{L}(P))$ is called the rough neutrosophic set [42] in (Y, R).

Definition 2.11Refined Neutrosophic Sets

Let$X$ be a universe. A neutrosophic refined set (NRS) [49]A on X can be defined as follows:

$$A = \begin{Bmatrix} < x, (T_A^1(x), T_A^2(x), ..., T_A^p(x)), (I_A^1(x), I_A^2(x), ..., I_A^p(x)), \\ (F_A^1(x), F_A^2(x), ..., F_A^p(x)) > \end{Bmatrix}$$

Here, $T_A^1(x), T_A^2(x), ..., T_A^p(x) : X \to [0,1]$, $I_A^1(x), I_A^2(x), ..., I_A^p(x) : X \to [0,1]$, and $F_A^1(x), F_A^2(x), ..., F_A^p(x) : X \to [0,1]$. For any x ϵ X $(T_A^1(x), T_A^2(x), ..., T_A^p(x))$, $(I_A^1(x), I_A^2(x), ..., I_A^p(x))$ and $(F_A^1(x), F_A^2(x), ..., F_A^p(x))$ is the truth-membership sequence, indeterminacy-membership sequence and falsity-membership sequence of the element x, respectively.

Section 3 The contribution of the selected Indian researchers

3.1 Dr. Partha Pratim Dey

Dr. Partha Pratim Dey was born at Chak, P. O.- Islampur, Murshidabad, West Bengal, India, PIN-742304. Dr. Dey qualified CSIR-NET-Junior Research Fellowship (JRF) in 2008. His paper entitled"Fuzzy goal programming for multilevel linear fractional programming problem"coauthored with Surapati Pramanik was awarded as the best paper in West Bengal State Science and Technology Congress (2011) in mathematics. He obtained Ph. D. in Science from Jadavpur University, India in 2015.Title of his Ph. D. Thesis [70] is:"Some studies on linear and non-linear bi-level programming problems in fuzzy envieonment``. He continues his research in the feild of fuzzy multi-criteria decision making and extends them in neutrosophic environment. Curently, he is an assistant teacher of Mathematics in Patipukur Pallisree Vidyapith, Patipukur, Kolkata-48. His research interest includes decision making in neutrosophic environemnt and optimization.

Contribution:

In 2015, Dey, Pramanik, and Giri [71] proposed a novel MADM strategy based on extended grey relation analysis (GRA) in interval neutrosophic environment with unknown weight of the attributes. Maximizing deviation method is employed to determine the unknown weight information of the atributes. Dey et al. [71] also developed linguistic scale to transform linguistic variable into interval neutrosophic values. They employed the developed strategy for dealing with practical problem of selecting weaver for Khadi Institution. Partha Pratim Dey, coming from a weaver family, is very familiar with the parameters of weaving and criteria of selection of weavers. Several parameters are defined by Dey et al. [71] to conduct the study.

Dey et al. [72] proposed a TOPSIS strategy at first in single valued neutrosophic soft expert set environmnet in 2015. Dey et al. [72] determined the weights of the parameters by employing maximizing deviation method and demonstrated an illustrative example of teacher selection problem. According to Google Scholar Citation, this paper [72] has been cited by 15 studies so far.
In 2015, Dey et al. [73] established TOPSIS startegy in generalized neutrosophic soft set environmnet and solved an illustrative MAGDM problem. In neutrosophic soft set environment, Dey et al. [74] grounded a new MADM strategy based on grey relational projection technique.

In 2016, Dey et al. [75] developed two new strategies for solving MADM problems with interval-valued neutrosophic assessments. The empolyed measures [75] are namely, i) weighted projection measure and ii) angle cosine and projection measure. Dey et al. [76] defined Hamming distance function and Euclidean distance function between bipolar neutrosophic sets. In the same study, Dey et al. [76] defined bipolar neutrosophic relative positive ideal solution (BNRPIS) and neutrosophic relative negative ideal solution(BNRNIS) and developed an MADM strategy in bipolar neutrosophic environemnt.

Deyet et al. [77] presented a GRA strategy for solving MAGDM problem under neutrosophic soft environment and solved an illustrative numerical example to show the effectiveness of the proposed strategy.
In 2016, Dey et al. [78] discussed a solution strategy for MADM problems with interval neutrosophic uncertain linguistic information through extended GRA method. Dey et al. [78] also proposed Euclidean distance between two interval neutrosophic uncertain linguistic values.

Pramanik, Dey, Giri, and Smarandache [79] defined projection, bidirectional projection and hybrid projection measures between bipolar neutrosophic sets in 2017 and proved their basic properties. In the same study [79], the same authors developed three new MADM strategies based on the proposed projection measures. They validated their result by solving a numerical example of MADM.

In 2017, Pramanik, Dey, Giri, and Smarandache [80] defined some operation rules for neutrosophic cubic sets and introduced the Euclidean distance between them.nThe authors also defined neutrosophic cubic positive and negative ideal solutions and established a new MADM strategy. In 2018, Dey, Pramanik, Ye and Smarandache [81] introduced cross entropy and weighted cross entropy measures for bipolar neutrosophic sets and interval bipolar neutrosophic sets and proved their basic properties. The authors also developed two new multi-attribute decision-making strategies in bipolar and interval bipolar neutrosophic set environment. The authors solved two illustrative numerical examples and compared the obtained results with existing strategies to demonstrate the feasibility, applicability, and efficiency of their strategies.

Pramanik, Dey and Giri [82] defined hybrid vector similarity measure between single valued refined neutrosophic sets (SVRNSs) and proved their basic properties and developed an MADM strategy and employed them to solve an illustrative example of MADM in SVRNS environment.

Pramanik, Dey and Smarandache [83] defined the correlation coefficient measure $Cor\ (L_1, L_2)$ between two interval bipolar neutrosophic sets (IBNSs) L_1, L_2 and proved the following properties:

(1) $Cor\ (L_1, L_2) = Cor\ (L_2, L_1)$;

(2) $0 \leq Cor\ (L_1, L_2) \leq 1$;

(3) $Cor\ (L_1, L_2) = 1$, if $L_1 = L_2$.

In the same study, the authors defined weighted correlation coefficient measure $Cor_w(L_1, L_2)$ between two IBNSs L_1, L_2 and established the following properties:

(1) $Cor_w(L_1, L_2) = Cor_w\ (L_2, L_1)$;

(2) $0 \leq Cor_w(L_1, L_2) \leq 1$;

(3) $Cor_w(L_1, L_2) = 1$, if $L_1 = L_2$.

The authors [83] also developed a novel MADM straegy based on weighted correlation coefficient measure and empolyed to solve an investment problem and compared the solution with existing startegies.

Pramanik, Dey, and Smarandache [84] defined Hamming and Euclidean distances measures, similarity measures based on maximum and minimum operators between two IBNSs and proved their basic properties. In the same research, Pramanik et al. [84] deveolped a novel MADM strategy in IBNS environment.

In fuzzy environment, work of Dey and Pramanik [85] obtained the best paper award in Mathematics in 2011 at 18th West Bengal State Science & Technology Congress Tilte of the paper was:' Fuzzy goal programming for multilevel linear fractional programming problems'.

In 2015, Dr. Dey obtained "*Diploma Certificate"* from *Neutrosophic Science InternationalAssociation (NISA)* for his outstanding performance in neutrosophic research. He was awarded the certificate of outstanding contribution in reviewing for the International Journal "Neutrosophic Sets and Systems". His works in neutrosophics draw much attention of the researchers international level. According to "*ResearchGate*" a social networking site for scientists and researchers, citation of his research exceeds 200. He is an active member of ''*Indian society for neutrosophic study*''.

Dr. Dey is very much intersted in neutrosophic study. He continues his research work with great mathematician like Prof. Florentin Smarandache and Prof. Jun Ye.

3.2 Kalyan Mondal

Kalyan Mondal was born at Shantipur, Nadia, West Bengal, India, Pin-741404. He qualified CSIR-NET-Junior Research Fellowship (JRF) in 2012. He is a research scholar in Mathematics of Jadavpur University, India since 2016. Title of his Ph. D. thesis is: "Some decision making models based on neutrosophic strategy". His paper entiled "*MAGDM based on contra-harmonic aggregation operator in neutrosophic number (NN) environmen*t'' coauthored with Surapsati Pramanik and Bibhas C. Giri was awarded outstanding paper in West Bengal State Science and Technology Congress (2018) in mathematics. He continues his research in the field neutrosophic multi-attribute decision making; aggregation operators; soft computing; pattern recognitions; neutrosophic hybrid systems, rough neutrosophic sets, neutrosophic numbers, neutrosophic game theory, neutrosophic algebraic structures. Presently, he is an assistant teacher of Mathematics in Birnagar High School (HS) Birnagar, Ranaghat, Nadia, Pin-741127, West Bengal, India.

Contribution:

In 2014, Mondal and Pramanik [86]initiated to study teacher selection problem using neutrosophic logic.

Pramanik and Mondal [87] defined cosine similarity measure for rough neutrosophic sets as $C_{RNS}(A, B)$ between two rough neutrosophic sets A, B and established the following properties:

(1) $C_{RNS}(A, B) = C_{RNS}\ (B, A)$;

(2) $0 \leq C_{RNS}(A, B) \leq 1$;

(3) $C_{RNS}(A, B) = 1$, iff $A = B$.

In the same study, Pramanik and Mondal [87] applied cosine similarity measure for medical diagnosis.

Mondal et al. [88] proposed a rough cotangent similarity measure in 2015 and studied some of its basic properties. The authors demonstrated an application of cotangent similarity measure of rough neutrosophic sets for medical diagnosis.

Pramanik and Mondal [89] introduced interval neutrosophic MADM strategy with completely unknown attribute weight information based on extended grey relational analysis.

In 2015, Mondal and Pramanik [90] presents rough neutrosphic MADM strategy based on GRA. They also extended the neutrosophic GRA strategy to rough neutrosophic GRA strategy and applied it to MADM problem. The authors first defined accumulated geometric operator to transform rough neutrosophic number (neutrosophic pair) to single valued neutrosophic number.

In 2015, Mondal and Pramanik [91] presented a neutrosophic MADM strategy for school choice problem. The authors used five criteria to modeling the school choice problem in neutrosophic environment.

In 2015, Mondal and Prammanik [92] defined cotangent similarity measure for neutrosophic sets as $COT_{NRS}(N, P)$ between two refined neutrosophic sets N, P and established the following properties:

(1) $COT_{NRS}(N, P) = COT_{NRS}(P, N)$;

(2) $0 \leq COT_{NRS}(N, P) \leq 1$;

(3) $COT_{NRS}(P, N) = 1$, if $P = N$.

In the same study, Mondal and Pramanik [92] presented an application of cotangent similarity measure of neutrosophic single valued sets in a decision making problem for educational stream selection.

Mondal and Pramanik [93] also defined rough accuracy score function and proved their basic properties. The authors also introduced entropy based weighted rough accuracy score value. The authors developed a novel rough neutrosophic MADM startegy with incompletely known or completely unknown attribute weight information based on rough accuracy score function.

Pramanik and Mondal [94] presented rough Dice and Jaccard similarity measures between rough neutrosophic sets. The authors proposed weighted rough Dice and Jaccard similarity measures, and proved their basic properties. The authors presented an application of rough neutrosophic Dice and Jaccard similarity measures in medical diagnosis.

Mondal and Pramanik [95] defined tangent similarity measure and proved their basic properties. In the same study, Mondal and Pramanik developed a novel MADM strategy for MADM problems in SVNS environment. The authors resented two illustrattive exaxmples, namely selection of educational stream and medical diagnosis to demonstrate the feasibility, and applicability of the proposed MADM strategy.

Mondal and Pramanik [96] studied the quality clay-brick selection strategy based on MADM with single valued neutrosophic GRA.The authors used neutrosophic grey relational coefficient on Hamming distance between each alternative to ideal neutrosophic estimates reliability solution and ideal neutrosophic estimates unreliability solution. They also used neutrosophic relational degree to determine the ranking order of all alternatives.

In 2015, Mondal and Pramanik [97] defined a refined tangent similarity measure strategy of refined neutrosophic sets and proved its basic properties. They presented an application of refined tangent similarity measure in medical diagnosis.

Mondal and Pramanik [98] introduced cosine, Dice and Jaccard similarity measures of interval rough neutrosophic sets and proved their basic properties. They developed three MADM strategies based on interval rough cosine, Dice and Jaccard similarity measures and presented an illustrative example, namely selection of best laptop for random use.

In 2016, Mondal and Pramanaik [47] defined rough tri-complex similarity measure in rough neutrosophic environment and proved its basic properties. In the same study, Mondal and Pramnaik [47] developed a novel MADM strategy for dealing with MADM problem in rough tri-complex neutrosophic envioronment. Mondal, Pramanik, and Smarandache [48] introduced the rough neutrosophic hyper-complex set and the rough neutrosophic hyper-complex cosine function in 2016, and proved their basic properties. They also defined the rough neutrosophic hyper-complex similarity measure and proved their basic properties. They also developed a new MADM strategy to deal with MADM problems in rough neutrosophic hyper-complex set environment. They presented a hypothetical application to the selection problem of best candidate for marriage for Indian context.

Mondal, Pramanik, and Smarandache [99] defined rough trigonometric Hamming similarity measures and proved their basic properties. In the same study, Mondal et al. [99] developed a novel MADM strategies to solve MADM problems in rough neutrosophic environment. The authors provided an application, namely selection of the most suitable smart phone for rough use.

In 2017, Mondal, Pramanik and Smarandache [100] developed a new MAGDM strategy by extending the TOPSIS strategy in rough neutrsphic environment, called rough neutrosophic TOPSIS strategy for MAGDM. They also proposed rough neutrosophic aggregate operator and rough neutrosophic weighted aggregate operator. Finally, the authors solved a numerical example to demonstrate the applicability and effectiveness of the proposed TOPSIS startegy.

Mondal, Pramanik, Giri and Smarandache [101] proposed neutrosophic number harmonic mean operator (NNHMO) and neutrosophic number weighted harmonic mean operator NNWHMO and cosine function to determine unknown criterion weights in neutrosophic number (NN) environment. The authors developed two strategies of ranking NNs based on score function and accuracy function. The authors also developed two novel MCGDM strategies based on the proposed aggregation operators. The authors solved a hypothetical case study and compared the obtained results with other existing strategies to demonstrate the effectiveness of the proposed MCGDM strategies. The significance of these stratigies is that they combine NNs with harmonic aggregation operators to cope with MCGDM problem.

In 2018, Mondal, Pramanik and Giri [102] inroduced hyperbolic sine similarity measure and weighted hyperbolic sine similarity measure namely, SVNHSSM(A, B) for SVNSs. They proved the following basic properties.

1. $0 \le$ SVNHSSM(A, B) ≤ 1
2. SVNHSSM(A, B) = 1 if and only if $A = B$
3. SVNHSSM (A, B) = SVNHSSM(B, A)
4. If R is a SVNS in X and $A \subset B \subset R$ then SVNHSSM(A, R) $\le$ SVNHSSM(A, B) and SVNHSSM(A, R) $\le$ SVNHSSM(B, R).

The authors also defined weighted hyperbolic sine similarity measure for SVNS namely, SVNWHSSM(A, B) and proved the following basicproperties.

1. $0 \le$ SVNWHSSM(A, B) ≤ 1
2. SVNWHSSM (A, B) = 1 if and only if $A = B$
3. SVNWHSSM (A, B) = SVNWHSSM(B, A)
4. If R is a SVNS in X and $A \subset B \subset R$ then SVNWHSSM (A, R) $\le$ SVNWHSSM(A, B) and SVNWHSSM (A, R) $\le$ SVNWHSSM (B, R).

The authors defined compromise function to determine unknown weight of the attributes in SVNS environment. The authors developed a novel MADM strategy based on the proposed weighted similarity measure. Lastly, the authors solved a numerical example and compared the obtained results with the existing strategies to demonstrate the effectiveness of the proposed MADM strategy.

Mondal, Pramanik, and Giri [103] defined tangent similarity measure and proved its properties in interval valued neutrosophic environment. The authors developed a novel MADM strategy based on the proposed tangent similarity measure in interval valued neutrosophic environment. The authors also solved a numerical example namely, selection of the best investment sector for an Indian government employee. The authors also presented a comparative analysis.

Mondal et al. [104] employed refined neutrosophic set to express linguistic variables. The authors proposed linguistic refined neutrosophic set. The authors developed an MADM strategy based on linguistic refined neutrosophic set. The authors also proposed an entropy method to determine unknown weight of the criterion in linguistic neutrosophic refined set environment. They presented an illustrative example of constructional spot selection to show the feasubility and applicability of the proposed strategy.

Mr. Kalyan Mondal is a young and hardworking researcher in neutrosophic field. He acts as an area editor of international journal,"*Journal of New Theory"* and acts as a reviewer for different international peer reviewed journals. In 2015, Mr. Mondal was awarded Diploma certificate from *Neutrosophic Science InternationalAssociation (NISA)* for his outstanding performance in neutrosophic research. He was awarded the certificate of outstanding contribution in reviewing for the International Journal "*Neutrosophic Sets and Systems*''. His works in neutrosophics draw much attention of the researchers at international level. According to "*Researchgate*'', citation of his research exceeds 430.

3.3 Dr. Pranab Biswas

Pranab Biswas obtained his Bachelor of Science degree in Mathematics and Master degree in Applied Mathematics from University of Kalyani. He obtained Ph. D. in Science from Jadavpur University, India. Title of his thesis is "Multi-attribute decision making in neutrosophic environment".

He is currently an assistant teacher of Mathematics. His research interest includes multiple criteria decision making, aggregation operators, soft computing, optimization, fuzzy set, intuitionistic fuzzy set, neutrosophic set.

Contribution:

In 2014, Biswas, Pramanik and Giri [105] proposed entropy based grey relational analysis strategy for MADM problem with single valued neutrosophic attribute values. In neutrosophic environment, this is the first case where GRAwas applied to solve MADM problem. The authors also defined neutrosophic relational degree. Lastly, the authors provided a numerical example to show the feasibility and applicability of the developed strategy.

In 2014, Biswas et al. [106] introduced single –valued neutrosophic MADM strategy with incompletely known and completely unknown attribute weight information based on modified GRA.The authors also solved an optimization model to find out the completely unknown attribute weight by ustilizing Lagrange function. At the end, the authors provided an illustrative example to show the feasibility, practicalitry and effectiveness of the proposed strategy.

Biswas et al. [69] introduced a new strategy called “Cosine similarity based MADM with trapezoidal fuzzy neutrosophic numbers”.The authors also established expected interval and the expected value for trapezoidal fuzzy neutrosophic number and cosine similarity measure of trapozidal fuzzy neutrosophic numbers.

In 2015, Biswas et al. [107] extended TOPSIS strategy for MAGDM in neutrosophic environment. In the study, rating values of alternative are expressed by linguistic terms such as *Good*, *Very Good*, *Bad*, *Very Bad*, etc. and these terms are scaled with single-valued neutrosophic numbers. Single-valued neutrosophic set-based weighted averaging operator is used to aggregate all the individual decision maker’s opinion into one common opinion for rating the importance of criteria and alternatives. The authors provided an illustrative example to demonstrate the proposed TOPSIS strategy.

Biswas et al. [108] further extened the TOPSIS strategy for MAGDM in single-valued neutrosophic environment. The authors developed a non-linear programming based strategy to study MAGDM problem. In the same study, the authors converted the single valued neutrosophic numbers into interval numbers. The authors employed nonlinear programming model to determine the relative closeness co-efficient intervals of alternatives for each decision maker. Then, the closeness co-efficient intervals of each alternative are aggregated according to the weight of decision makers. Further, the authors developed a priority matrix with the aggregated intervals of the alternatives. The authors obtained the ranking order of all alternatives by computing the optimal membership degrees of alternatives with the ranking method of interval numbers. Finally, the authors presented an illustrative example to show the effectiveness of the proposed strategy.

In 2015, Pramanik, Biswas, and Giri [109] proposed two new hybrid vector similarity measures of single valued and interval neutrosophic sets by hybriding the concept of Dice and cosine similarity measures.The authors also proved their basic properties. The authors also presented their applications in multi-attribute decision making in neutrosophic environment.

Biswas et al. [110] proposed triangular fuzzy number neutrosophic sets by combining triangular fuzzy number with single valued neutrosophic set in 2016. Biswas et al. [110] also defined some of its operational rules. The authors defined triangular fuzzy number neutrosophic weighted arithmetic averaging operator and triangular fuzzy number neutrosophic weighted geometric averaging operator to aggregate triangular fuzzy number nuetrosophic set. The authors also established some of their properties of the proposed operators. The authors also presented an MADM strategy to solve MADM in triangular fuzzy number neutrosophic set environment.

In 2016, Biswas et al. [111] defined score value, accuracy value, certainty value, and normalized Hamming distance of single valued neutrosophic hesitant fuzzy sets.The authors also defined positive ideal solution and negative ideal solution by score value and accuracy value. The authors calculated the degree of grey relational coefficent between each alternative and ideal alternative. The authors also determined a relative closeness coefficient to obtain the ranking order of all alternatives. Finally, the authors provided an illustrative example to show the validity and effectiveness of the proposed grey relational analysis based MADM strategy in single valued neutrosophic hesitant fuzzy set environment.

Biswas, Pramanik, and Giri [112] proposed a class of distance measures for single-valued neutrosophic hesitant fuzzy sets in 2016 and proved their properties with variational parameters. The authors applied weighted distance measures to calculate the distances between each alternative and ideal alternative in the MADM problems. The authors developed a MADM strategy based on the proposed distance functions in single valued neutrosophic hesitant fuzzy set environment. The authors provided an illustrative example to verify the proposed strategy and to show its fruitfulness. The authors also compared the proposed strategy with other existing startegies for solving MADM in single valued neutrosophic hesitant fuzzy set environment.

Biswas et al. [113] introduced single-valued trapezoidal neutrosophic number (SVTrNN), which is a special case of single-valued neutrosophic number and developed a ranking method for ranking SVTrNNs. The authors presented some operational rules as well as cut sets of SVTrNNs. The authors defined the value and ambiguity indices of truth, indeterminacy, and falsity membership functions of SVTrNNs. Using the proposed ranking strategy and proposed indices, the authors developoed a new MADM strategy to solve MADM problem in which the ratings of the alternatives over the attributes are expressed in terms of TrNFNs. Finally, the authors provided an illustrative example to demonstrate the validity and applicability of the proposed MADM strategy with SVTrNNs.

In 2016, Biswas et al.[114] introduced the concept of SVTrNN in the form:

$\tilde{A}_1 = \langle (a_{11}, a_{21}, a_{31}, a_{41}), (b_{11}, b_{21}, b_{31}, b_{41}), (c_{11}, c_{21}, c_{31}, c_{41}) \rangle$,where $a_{11}, a_{21}, a_{31}, a_{41}, b_{11}, b_{21}, b_{31}, b_{41}, c_{11}, c_{21}, c_{31}, c_{41}$ are real numbers and satisfy the inequality

$c_{11} \le b_{11} \le a_{11} \le c_{21} \le b_{21} \le a_{21} \le a_{31} \le b_{31} \le c_{31} \le a_{41} \le b_{41} \le c_{41}$.

The authors defined some arithmetical operational rules. The authors also defined value index and ambiguity index of SVTrNNs and established some of their properties. The authors developed a ranking strategy with the proposed indicess to rank SVTrNNs. The authors developed a new MADM strategy to solve MADM problems in SVTrNN environment.

Biswas et al. [115] extended the TOPSIS strategy of MADM problems in single-valued trapezoidal neutrosophic number environment. In their study, the attribute values are expressed in terms of single-valued trapezoidal neutrosophic numbers. The authors deal with the situation where the weight information of attribute is incompletely known or completely unknown. The authors developed an optimization model using maximum deviation strategy to obtain the weight of the attributes. The authors also illustrated and validated the proposed TOPSIS strategy by solving a numerical example of MADM problems.

Biswas et al. [116] introduced a new neutrosophic numbers called interval neutrosophic trapezoidal number (INTrN) characterized by interval valued truth, indeterminacy, and falsity membership degrees and defined some arithmetic operations on INTrNs, and normalized Hamming distance between INTrNs. In the same study, Biswas et al. [116] developed a new MADM strategy, where the rating values of alternatives over the attributes and the importance of weight of attributes assume the form of INTrNs. Biswas et al. [116] employed the entropy strategy to determine thr attribute weight and then used it to calculate aggregated weighted distance measure and determined ranking order of alternatives with the help of aggregated weighted distance measures. Biswas et al. [116] also solved an illustrative example to show the feasibility, applicability and effectiveness of the proposed strategy.

Dr. Biswas's work [117] obtained outstanding paper award at "Second Regional Science and Technology Congress, 2017'' held at University of Kalyani, Nadia, West Bengal, India. His resesrch interest includes fuzzy, intuitionistic fuzzy and neutrosophic decision making.

Dr. Pranab Biswas is a young and hardworking researcher in neutrosophic field. In 2015, Dr. Biswas was awarded "Diploma Certificate" from *Neutrosophic Science International Association (NISA)* for his outstanding performance in neutrosophic research. He was awarded the certificate of outstanding contribution in reviewing for the International Journal "Neutrosophic Sets and Systems'' in 2018. According to "*Researchgate*'', citation of his research exceeds 375. Research papers of Biswas et al. [105, 112] received the best paper award from "Neutrosophic Sets and Systems'' for volume 2, 2014 and volume 12, 2016. His works in neutrosophics draw much attention of the researchers in national as well international level. His Ph. D. thesis entilted:"Multi-attribute decision making in neutrosophic environment" was awarded "*Doctorate of Neutrosophic theory*" by Indian Society for Neutrosophic Study (ISNS) with sponsorship by Neutrosophic Science International Association (NSIA).

3.4 Dr.Durga Banerjee

Durga Banerjee passed M. Sc. from Jadavpur University in 2005. In 2017, D. Banerjee obtained Ph. D. Degree in Science from Jadavpur University. Her research interest includes operations research, fuzzy optimization, and neutrosophic decision making. Title of her Ph. D. Thesis [118] is: "Some studies on decision making in an uncertain environment''. Her Ph. D. thesis comprises of few chapters dealing with MADM in neutrosophic environment.

Contribution:

In 2016, Pramanik, Banerjee, and Giri [119] introduced refined tangent similarity measure.The authors presented an MAGDM model based on tangent similarity measure of neutrosophic refined set. The authors also introduced simplified form of tangent similarity measure. The authors defined new ranking method based on refined tangent similarity measure. Lastly, the authors solved a numerical example of teacher selectionin in neutrosophic refined set environment to see the effectiveness of the proposed strategy.

In 2016, Banerjee et al.[120] developed TOPSIS startegy for MADM in refined neutrosophic environment. The authors also provided a numerical example to show the feasibility and applicability of the proposed TOPSIS strategy.

In 2017, Banerjee, Pramanik, Giri and Smarandache [121] at first developed an MADM strategy in neutrosophic cubic set environment using grey relational analysis. The authors discussed about positive and negative grey relational coefficients,and weighted grey relational coefficients, Hamming distances for weighted grey relational coefficients and standard grey relational coefficient.

Her Ph. D. thesis [118] entilted:"Multi-attribute decision making in neutrosophic environment" was awarded "*Doctorate of Neutrosophic theory*" by the Indian Society for Neutrosophic Study (ISNS) with sponsorship by Neutrosophic Science International Association (NSIA). According to "*Researchgate*'', citation of his research exceeds 55.

3.5 Shyamal Dalapati

Shyamal Dalapati qualified CSIR-NET-Junior Research Fellowship (JRF) in 2017. He is a research scholar in Mathematics at the Indian Institute of Engineering Science and Technology (IIEST), Shibpur, West Bengal, India.Title of his Ph. D. thesis is:"Some studies on neutrosophic decision making". He continues his research in the field of neutrosophic multi attribute group decision making; neutrosophic hybrid systems; neutrosophic soft MADM . Curently, he is an assistant teacher of Mathematics His research interest includes decision making in neutrosophic environemnt and optimization.

Contribution:

In 2016, Dalapati and Pramanik [122] defined neutrosophic soft weighted average operator.They determined the order of the alternatives and identify the most suitable alternative based on grey relational coefficient. They also presented a numerical example of logistics center location selection problem to show the effectiveness and applicability of the proposed strategy.

Dalapati,Pramanik, and Roy [123] proposed modeling of logistics center location problem using the score and accuracy function, hybrid-score-accuracy function of SVNNs and linguistic variables under single-valued neutrosophic environment, where weight of the decision makers are completely unknown and the weight of criteria are incompletely known.

Dalapati, Pramanik, Alam, Roy, and Smaradache [124] defined IN-cross entropy measure in INS environment in 2017. The authors proved the basic properties of the cross entropy measure. The authors also defined weighted IN- cross entropy measure and proved its basic properties. They also introduced a novel MAGDM strategy based on weighted IN-cross entropy. Finally, the authors solved a MAGDM problem to show the feasibility and efficiency of the proposed MAGDM strategy.

Pramanik, Dalapati, Alam, and Roy [125] defined TODIM strategy in bipolar neutrosophic set environment to handle MAGDM. The authors proposed a new strategy for solving MAGDM problems. The authors also solved an MADM problem to show the applicability and effectiveness of the proposed startegy.

Pramanik, Dalapati, Alam, and Roy [126] introduced the score and accuracy functions for neutrosophic cubic sets and prove their basic properties in 2017. The authors developed a new strategy for ranking of neutrosophic cubic numbers based on the score and accuracy functions. The authors first developed a TODIM (Tomada de decisao interativa e multicritévio) stratey in the neutrosophic cubic set (NCS) environment strategy. The authors also solved an MAGDM problem to show the applicability and effectiveness of the developed strategy. Lastly, the authors conducted a comparative study to show the usefulness of proposed strategies.

In 2018, Pramanik, Dalapati, Alam, and Roy [127]extended the traditional VIKOR strategy to NC-VIKOR strategy and developed an NC-VIKOR based MAGDM strategy in neutrosophic cubic set environment. The authors defined the basic concept of neutrosophic cubic set. Then, the authors introduced neutrosophic cubic number weighted averaging operator and applied it to aggregate the individual opinion to one group opinion. The authors presented an NC-VIKOR based MAGDM strategy with neutrosophic cubic set. They also presented a sensitivity analysis. Finally, the authors solved an MAGDM problem to show the feasibility and efficiency of the proposed MAGDM strategy.

Pramanik, Dalapati, Alam, and Roy [128] extended the VIKOR strategy to MAGDM with bipolar neutrosophic environment. The authors introduced the bipolar neutrosophic numbers weighted averaging operator and applied it to aggregate the individual opinion to one group opinion. The authors proposed a VIKOR based MAGDM strategy with bipolar neutrosophic set. Lastly, the authors solved an MAGDM strategy to show the feasibility and efficiency of the proposed MAGDM strategy and presented a sensitivity analysis.

Pramanik, Dalapati, Alam, and Roy [129] studied some operations and properties of neutrosophic cubic soft sets.The authors defined some operations such as P-union, P-intersection, R-union, R-intersection for neutrosophic cubic soft sets (NCSSs). The authors proved some theorems on neutrosophic cubic soft sets.The authors also discussed various approaches of internal neutrosophic cubic soft sets (INCSSs) and external neutrosophic cubic soft sets (ENCSSs) and also investigated some of their properties.

Pramanik, Dalapati, Alam, Smarandache, and Roy [130] defined a new cross entropy measure in SVNS environment.The authors also proved the basic properties of the NS cross entropy measure. The authors defined weighted SN-cross entropy measure and proved its basic properties. At first the authors proposed an MAGDM strategy based on NS- cross entropy measure.

Pramanik, Dalapati, Alam, Roy, Smarandache [131] defined similarity measure between neutrosophic cubic sets and proved its basic properties. They developed a new MADM strategy basd on the proposed similarity measure. They also provided an illustrative example for MADM strategy to show its applicability and effectiveness.

Mr. Dalapati's neutrosophic paper [132] was awarded as the outstanding research paper at the "1st Regional Science and Technology Congress, 2016 in mathematics.

Mr. Shamal Dalapati is a young and hardworking researchers in neutrosophic field. In 2017, Mr. Dalapati was awarded "Diploma Certificate" from *Neutrosophic Science InternationalAssociation (NISA)* for his outstanding performance in neutrosophic research. His research articles receive more than sevent citations.

3.6 Prof.Tapan Kumar Roy

Prof. T. K. Roy, Ph. D. in mathematics, is a Professor of mathematics in Indian Institute of Engineering Science and Technology (IIEST), Shibpur. His main research interest includes neutrosophic optimization, neutrosophic game theory, decision making in neutrosophic environment, neutrosophy, etc.

Contribution:

In 2014, Pramanik and Roy [133] presented the framework of the application of game theory to Jammu Kashmir conflict between India and Pakistan. Pramanik and Roy [20] extended the concept of game

theoretic model [133] of the Jammu and Kashmir conflict in neutrosophic environment.
At first, Roy and Das[134] presented multi-objective non –linear programming problem based on neutrosophic optimization technique and its application in Riser design problem in 2015.
Roy, Sarkar, and Dey [133] presented a multi-objective neutrosophic optimization technique and its application to structural design in 2016.

In 2017, Roy and Sarkar [135-138] also presented several applications of neutrosophic optimization technique.

In 2017, Pramanik, Roy, Roy, and Smarandache [139] presented multi criteria decision making using correlation coefficient under rough neutrosophic environment. The authors defined correlation coefficient measure between any two rough neutrosophic sets and also proved some of its basic properties.

In 2018, Pramanik, Roy, Roy, and Smarandache [140] defined projection and bidirectional projection measures between interval rough neutrosophic sets and proved their basic properties. The authors developed two new MADM strategies based on interval rough neutrosophic projection and bidirectional projection measures. Then the authors solved a numerical example to show the feasibility, applicability and effectiveness of the proposed strategies.

In 2018, Pramanik, Roy, Roy, and Smarandache [141] proposed the sine, cosine and cotangent similarity measures of interval rough neutrosophic sets and proved their basic properties. The authors presented three MADM strategies based on proposed similarity measures. To demonstrate the applicability, the authors solved a numerical example. Prof. Roy did research work on decision making in SVNS, INS, neutrosophic hybrid environment [124-132, 139-141] with S. Pramanik, S. Dalapati, S. Alam and Rumi Roy.

His paper [142] together with S. Pramanik and S. Chackrabarti was awarded as the best research paper in 15th West Bengal State Science & Technology Congress, 2008 held on 28th February-29th February, 2008, at Bengal Engineering and Science University, Shibpur.
Prof. Roy is a great motivator and a very hardworking person. He works with Prof. Florentin Smarandache. According to "Googlescholar" his research gets citation over 2635.

3.7Prof.Bibhas C. Giri

Prof. Bibhas C.Giri is a Prof. of mathematics in Jadavpur University. He did his M.S. in Mathematics and Ph. D. in Operations Research both from Jadavpur University, Kolkata, India. His research interests include inventory/supply chain management, production planning and scheduling, reliability and maintenance.
He was a JSPS Research Fellow at Hiroshima University, Japan during the period 2002-2004 and Humboldt Research Fellow at Mannheim University, Germany during the period 2007-2008, Fulbright Senior Research Fellow at Louisiana State University in the year 2012.

Contribution:

Prof. Giri works with S. Pramanik, P. Biswas and P. P. Dey in neutrosophic environment. His neutrosophic paper [143] coauthored with Kalyan Mondal and Surapati Pramanik received the outstanding research paper award at the"1st Regional Science and Technology Congress, 2016 in mathematics. His neutrosophic paper [144] together with Kalyan Mondal and Surapati Pramanik received the best research paper in 25 th West Bengal State Science and Technology Congress 2018 in mathematics. His neutrosophic research work and vast contribution can be found in [71-80, 82, 101-119].

Prof. Giri is a great motivator. According to "*Googlescholar*', his research receives more than 4920 citations having h-index-31 and i-10 index-78.

3.8 Prof. Anjan Mukherjee

Anjan Mukherjee was born in 1955. He completed his B. Sc. and M. Sc. in Mathematics from University of Calcutta and Ph. D. from Tripura University. Currently, he is a Professor and Pro -Vice Chancellor of Tripura University. Under his guidance, 12 candidates obtained Ph. D. award. He has 30 years of research and teaching experience. His main research interest includes topology, fuzzy set theory, rough sets, soft sets, neutrosophic set, neutrosophic soft set, etc.

Contribution:

In 2014, Anjan Mukherjee and Sadhan Sarkar [145] defined the Hamming and Euclidean distances between two interval valued neutrosophic soft sets (IVNSSs). The authors also introduced similarity measures based on distances between two interval valued neutrosophic soft sets.The authors proved some basic properties of the similarity measures between two interval valued neutrosophic soft sets. They established an MADM strategy for interval valued neutrosophic soft set setting using similarity measures.

Mukherjee and Sarkar [146] also defined several distances between two interval valued neutrosophoic soft sets in 2014. The authors proposed similarity measure between two interval valued neutrosophic soft sets. The authors also proposed similarity measure between two interval valued neutrosophic soft sets based on set theoretic approach. They also presented a comparative study of different similarity measures.

Mukherjee and Sarkar [147]defined several distances between two neutrosophoic soft sets.The authors also defined similarity measure between two neutrosophic soft sets.The authors developed an MADM strategy based on the proposed similarity measure.

Mukherjee and Sarkar [148] proposed a new method of measuring degree of similarity and weighted similarity between two neutrosophic soft sets and studied some properties of similarity measure. Based on the comparison between the proposed strategy [148] and existing strategies introduced by Mukherjee and Sarkar[147], the authors found that the proposed strategy [148] offers strong similarity measure. The authors also proposed a decision making strategy based on similarity measure.

Prof. Anjan Mukherjee evaluated many Ph. D. theses. Among them, the Ph. D. thesis of Durga Banerjee [118] dealing with neutrosophic decision making was evaluated by Prof. Anjaan Mukherjee. Research of Prof. Mukherjee receives more than 700 citations for his works. Prof. Mukherjee is working with his group members with neutrosophic soft sets and its applications.

3.9 Dr.Pabitra Kumar Maji

Dr. Pabitra Kumar Maji, M. Sc., Post Doc., is an Assistant Professor of mathematics in Bidhan Chandra College, Asansol, West bengal. He works on soft set, fuzzy soft set, intuitionistic fuzzy set, fuzzy set, neutrosophic set, neutrosophic soft set, etc.,

Contribution:

In 2011, Maji [149] presented an application of neutrosophic soft set in object recognition problem based on multi-observer input data set. The author also introduced an algorithm to choose an appropriate object from a set of objects depending on some specified parameters.

In 2014, Maji, Broumi, and Smarandache [150] defined intuitionistic neutrosophic soft set over ring and proved some properties related to this concept. They also defined intersection, union, AND and OR operations over ring (INSSOR). Finally, the authors defined the product of two intuitionistic neutrosophic soft set over ring.

In 2015, Maji [151] presented weighted neutrosophic soft sets. The author presented an application of weighted neutrosophic soft sets in MADM problem. According “Googlescholar’’, his publication includes 20 research paper having citations 5948.

Maji [152] studied the concept of weighted neutrosophic soft sets. The author considered a multi-observer decision-making problem as an application of weighted neutrosophic soft sets. We have considered here a recognition strategy based on multi-observer input parameter data set.

3.10 Dr. Harish Kumar Garg

Dr. Harish Garg is an Assistant Professor in the School of Mathematics, Thapar Institute of Engineering &Technology (Deemed University) Patiala. He completed his post graduation (M.Sc) in

Mathematics from Punjabi University Patiala, India in 2008 and Ph.D. from Department of Mathematics, Indian Institute of Technology (IIT) Roorkee, India in 2013. His research interest includes neutrosophic decision-making, aggregation operators, reliability theory, soft computing technique, fuzzy and intuitionistic fuzzy set theory, etc.

Contribution:

In 2016, Garg and Nancy [153] defined some operations of SVNNs such as sum, product, and scalar multiplication under Frank norm operations. The authors also defined some averaging and geometric aggregation operators and established their basic properties.The authors also established a decision-making strategy based on the proposed operators and presented an illustrative numerical example.

In 2017, Garg and Nancy [154] developed a nonlinear programming (NP) model based on TOPSIS to solve decision-making problems. At first, the authorsconstructed a pair of the nonlinear fractional programming model based on the concept of closeness coefficient and then transformed it into the linear programming model.

Garg and Nancy [155] defined some new types of distance measures to overcome the shortcomings of the existing measures for SVNSs. The authors presented a comparison between the proposed and the existing measures in terms of counter-intuitive cases for showing validity. The authors also demonstrated the defined measures with hypothetical case studies of pattern recognition as well as medical diagnoses.

Garg and Nancy [156] studied the entropy measure of order α for single valued neutrosophic numbers. The authors established some desirable properties of entropy measure. The author also developed a MADM strategy based on entropy measures and solved a numerical example of investment problem.

Nancy and Garg [157] proposed an improved score function for ranking the single as well as interval-valued neutrosophic sets by incorporating the idea of hesitation degree between the truth and false degrees. The authors also presented an MADM strategy based on proposed function and solved a numerical example to show its practicality and effectiveness.

Garg and Nancy [158] introduced some new linguistic prioritized aggregation operators in the linguistic single-valued neutrosophic set (LSVNS) environment.The authors proposed some prioritized weighted and ordered weighted averaging as well as geometric aggregation operators for a collection of linguistic single-valued neutrosophic numbers and established their basic properties. The authors also proposed MADM strategy and solved a numerical example.

Dr. Garg research receives more than 2000 citations. Dr. Garg acts an active reviewer for reputed international journals and received certificate of outstanding in reviewing from “Computer & Industrial Engineering’’, “Engineering Applications of Artificial Intelligence’’, “Applied Soft Computing’’, “Applied Mathematical Modeling’’, etc. Dr. Garg acts as editor for many international journals.

3.11 Dr.Sukanto Bhattacharya

Sukanto Bhattacharya is a faculy member and associated with Deakin Business School, Deakin University.

Sukanto Bhattacharya [159] is the first researcher who employed utility theory to financial decision-making and obtained Ph. D. for applying neutrosophic probability in finance. His Ph. D. thesis covers a substantial mosaic of related concepts in utility theory as applied to financial decision-making. The author reviewed some of the classical notions of Benthamite utility and the normative utility paradigm. The author proposed some key theoretical constructs like the neutrosophicnotion of perceived risk and the entropic utility measure.

Khoshnevisan, and Bhattacharya [160] added a neutrosophic dimension to the problem of determining the conditional probability that a financial misrepresentation of the data set.

Prof. Bhattacharya is an active researcher and his works in neutrosophics are found in [159-163]. His research receives more than 380 citations.

4. Conclusions

We have presented a brief overview of the contributions of some selected Indian researchers who conducted research in neutrosophic decision making. We briefly presented the contribution of the selected Indian neutrosophic researchers in MADM. In future, the contribution of Indian researchers such as W. B. V. Kandasamy, Pinaki Majumdar,Surapati Pramanik, Samarjit Kar, and other Indian mathematicians in developing neutrosophics can be studied. The study can also be extended for mathematicians from other countries who contributed in developing neutrosophic science. Decision making in neutrosophic hybrid environment is gaining much attention. So it is a promising field of research in different neutrosophic hybrid environment and the real cahllenge lies in the applications of the developed theories. Since some of the selected researchers are young, it is hoped that the researchers will do more creative works and new research regarding their contributions will have to be conducted in future.

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