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

Surapati Pramanik[1], Rama Mallick[3], Anindita Dasgupta[3]

[1,3]Nandalal Ghosh B.T. College, Panpur, P.O.-Narayanpur, District –North 24 Parganas, Pin code-743126, West Bengal, India.
[1]E-mail: sura_pati@yahoo.co.in, [2]Email: aninditadasgupta33@gmail.com
[2]Umeschandra College, Department of Mathematics, Surya Sen Street ,Kolkata-700012, West Bengal, India, [1]Email: ramamallick23@gmail.com

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 imprecisionor vagueness.Imprecisionor 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 set or SVNS 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 work 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 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 concept related to neutrosophic set. Section 3 presents the contribution of the selected Indian researchers. Section 4 presents conclusion and future scope of research.

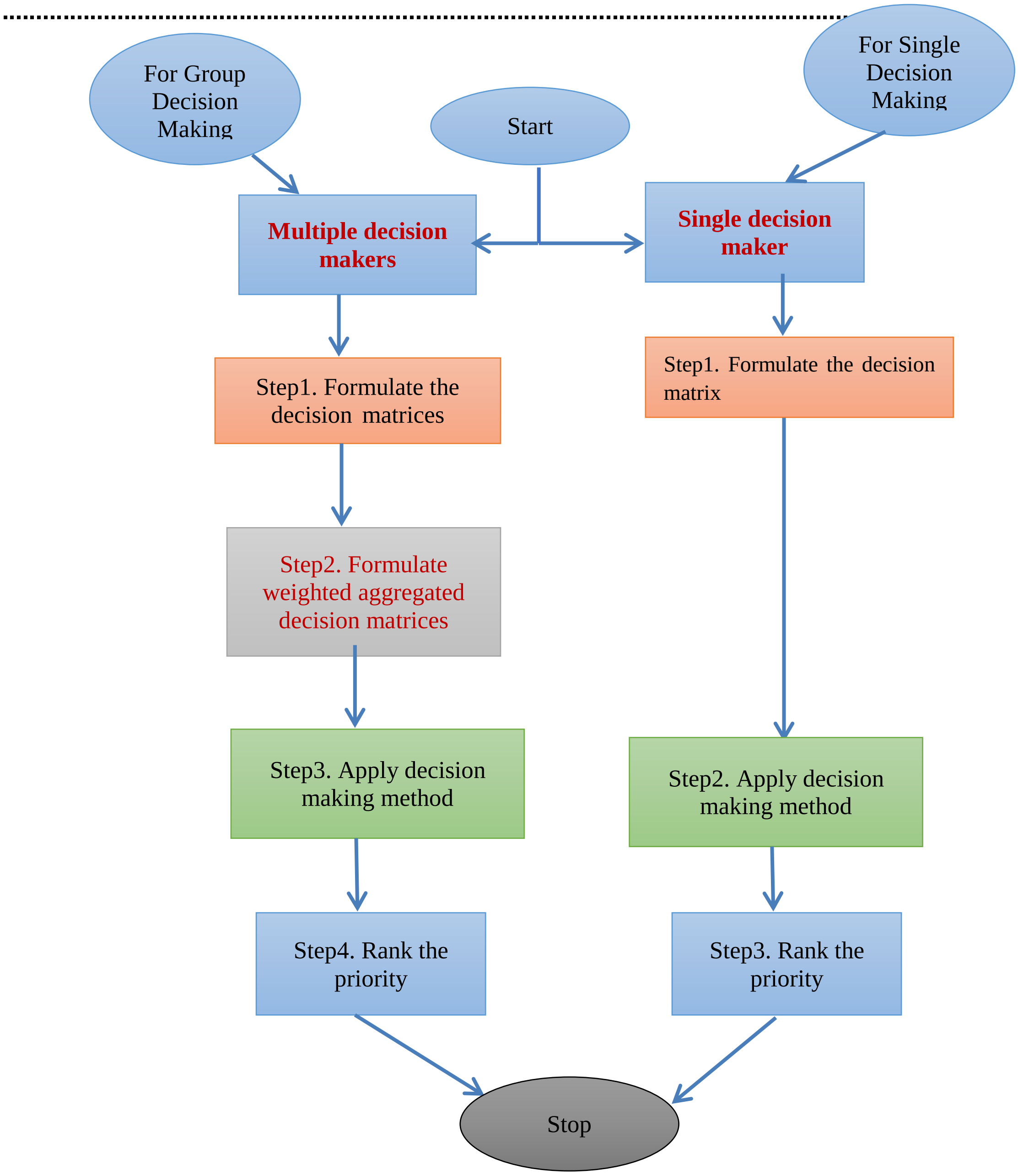

Figure 1. Decision making steps

2 Preliminaries

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

Definition.2.1 Neutrosophic Set

Let U be the universe. A neutrosophic set [17] (NS) P in U 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 elements of [0,1]. It can be defined as

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

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

Definition 2.2 Single valued neutrosophic set

Let X be a space of points (objects) with generic elements in Đ denoted by x. A single valued neutrosophic set [19] P is characterized by 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 Đ ,$T_P(x),I_P(x),F_P(x) \in [0, 1]$. A SVNS A can be written as

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

Definition 2.3 Interval valued neutrosophic set

Let N be a space of points (objects) with generic elements in X denoted by x. An interval valued neutrosophic set [18] 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 $x \epsilon X$, $T_P(x),I_P(x),F_P(x) \subset [0, 1]$. An IVNS P can be written as

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

Definition 2.4: Bipolar neutrosophic set

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

An empty bipolar neutrosophic set B_1=< $T_1^m, I_1^m, F_1^m, T_1^n, I_1^n, F_1^n$ > is defined as $T_1^m = 0, I_1^m = 0, F_1^m = 1$ and $T_1^n = -1, I_1^n = 0, F_1^n = 0$

Definition 2.5: Neutrosophich hesitant fuzzy set

Let μ be a fixed set, a neutrosophic hesitant fuzzy set [39] (NHFS) on X is defined by:

$M=\{<x,T(x),I(x),F(x)>|x \in \mu \}$,where $T(x)=\{ \alpha|\alpha \in T(x)\}$,I(x)=$\{\beta|\beta \in I(x)\}$ and F(x)=$\{\gamma|\gamma \in F(x)\}$

Are three sets of some different values in interval $[0,1]$, which represents the possible truth-membership hesitant degrees,indeterminacy-membership hesitant degrees, and falsity-membership hesitant degrees of the element x϶μ to the set N , and satisfies these limits :

$\alpha \epsilon [0,1], \beta \epsilon [0,1], \gamma \epsilon [0,1]$ and $0 \leq sup\, \alpha^+ + sup\beta^+ + sup\gamma^+ \leq 3$ 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 $m = \{T(x), I(x), F(x)\}$ is called a neutrosophic hesitant fuzzy element (NHFE) which is the basic unit of the NHFS and is denotedbythesymbol $M=\{T,I,F\}$.

Definition 2.6: Interval neutrosophic hesitant fuzzy set

Let Ω be a unempty fixed set, an INHFS [67] on Ω is defined as

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

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

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

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 neutrosophic set [68] (TFNS) P in X is defined by
$P=\{<x:T_P(x), I_P(x), F_p(x)>, x\epsilon X\}$,
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, denotes the possible truth-membership, indeterminacy-membership and a falsity-membership degree of x in p and for every $x \in X$
$0 \le T_P^3(x) + I_P^3(x) + F_P^3(x) \le 3$
The triangular fuzzy neutrosophic value (TFNV) P is symbolized by $P=<(l, m ,n),(p, q, r),(u, v, w)>$
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).

Definition2.8 Neutrosophic soft set

Let V be an initial universe set and E be a set of parameters. Consider $A \subset E$. Let $P(V)$ denotes 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 $\dddot{N} = \{< u, A (u), \lambda (u) >: u \in U\}$ 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 $\dddot{N} = <A, \lambda>$. We use $C\dddot{N}(U)$ as a notation which implies that collection of all neutrosophic cubic sets in U.

Definition 2.10 Rough Neutrosophic Sets

Let Y be a non empty set and R be an equivalence relation on Y . Let P be 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 (Y, R) denoted by $\underline{L}(P)$ and $\overline{L}(P)$ are respectively defined as follows:

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

Here $T_{\underline{L}(P)}(x)=\wedge_{y \in [x]_R} T_P(y)$,
$I_{\underline{L}(P)}(x)=\wedge_{y \in [x]_R} I_P(y)$,
$F_{\underline{L}(P)}(x)=\wedge_{y \in [x]_R} F_P(y)$,
$T_{\overline{L}(P)}(x)=\vee_{y \in [x]_R} T_P(y)$,
$I_{\overline{L}(P)}(x)=\vee_{y \in [x]_R} I_P(y)$,
$F_{\overline{L}(P)}(x)=\vee_{y \in [x]_R} F_P(y)$
So, $0 \le \sup T_{\underline{L}(P)}(x) + \sup I_{\underline{L}(P)}(x) + \sup F_{\underline{L}(P)}(x) \le 3$
$0 \le \sup T_{\overline{L}(P)}(x) + \sup I_{\overline{L}(P)}(x) + \sup F_{\overline{L}(P)}(x) \le 3$

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

Therefore, NS mapping $\underline{L}$, $\overline{L}$ $:L(Y) \to L(Y)$ 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 2.11 Refined Neutrosophic Sets

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

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

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 $x\epsilon X$ $\left(T_A^1(x), T_A^2(x), ..., T_A^p(x)\right)$, $\left(I_A^1(x), I_A^2(x), ..., I_A^p(x)\right)$ and $\left(F_A^1(x), F_A^2(x), ..., F_A^p(x)\right)$ is the truth-membership sequence, indeterminacy-membership sequence and falsity-membership sequence of the element x, respectively.

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 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. to conduct the study.

Dey et al. [72] proposed a TOPSIS strategy at first in single valued neutrosophic soft expert set environment 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.

Dey 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, the same authors [80] defined some operation rules for neutrosophic cubic sets and introduced the Euclidean distance between them. In the same study, Dey et al. [80] also definedneutrosophic cubic positive and negative ideal solutions and established a new MADM strategy.

In 2018, Pramanik, Dey, Jun 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. They also developed two new multi-attribute decision-making strategies in bipolar and interval bipolar neutrosophic set environment. They solved two illustrative numerical examples and compared obtained results with existing strategies to demonstrate the feasibility, applicability, and efficiency of their strategies.

Dey and his colleagues [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.

Dey et al. [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 research, Dey et al. [83] 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 $L_1 = L_2$.

Dey et al. [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.

Pramanik and Dey [85] developed at first goal programming model for solving bi-level linear programming problem with Smarandache number environment.

In 2015, he 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 international level. According to "*ResearchGate*" a social networking site for scientists and researchers, citation of his research exceeds 165. 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 aresearch 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 inBirnagar High School (HS) Birnagar, Ranaghat, Nadia, Pin-741127, West Bengal, India.

Contribution:

In 2014 K. Mondal and S. Pramanik [86]initiated to study teacher selection problem using neutrosophic logic. Mondal and Pramanik [86] proposed a new MAGDM startegy using the score and accuracy functions, hybrid score-accuracy functions of SVNNs. 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) $C_{\mathrm{RNS}}(A, B) = 1$, iff $A= B$.

In the same study, Pramanik and Mondal [87] applied cosine similarity measure for medical diagnosis and they also proposed some basic operational relations and weighted rough Dice and Jaccard similarity measures and proved some of their properties.They also applied the Dice and Jaccard similarity measures to a medical diagnosis problems.

Mondal et al. [88] proposed a refined cotangent similarity measure approach of single valued neutrosophic set in 2015 and studied some of it's properties. They demonstrated an application of cotangent similarity measure of neutrosophic single valued sets in a decision making problem for educational stream selection.

Pramanik and Mondal [89] introduced interval neutrosophic MADM problem with completely unknown attribute weight information based on extended GRA.Pramanik and Mondal [89] proposd interval neutrosophic grey relation coefficient for solving multiple attribute decision-making problem.

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

In 2015, Mondal and Pramanik[91] presented the application of single valued neutrosophic decision making model on school choice. They used five criteria to modeling the school choice problem in neutrosophic environment.

In 2015, Mondal and Prammanik [92] defined cotangent similarity measure for refined neutrosophic sets as $COT_{NRS}(N, P)$between two rough 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) $COT_{\mathrm{NRS}}(P, N) = 1$, 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.

In the same year, Mondal and Pramanik [93] also defined rough accuracy score function and proved their basic properties. They also introduced entropy based weighted rough accuracy score value. They 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. They proposed some basic operational relations, weighted rough Dice and Jaccard similarity measures, and proved theirbasic properties. They 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. They presented illustrattive exaxmples namely selection of educational stream and medical diagnosis to demonstrate the feasibility, and applicabilityof the proposed MADM strategy.

Mondal and Praamnik [96] studied the quality clay-brick selection strategy based on MADM with single valued neutrosophic GRA.They 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 (bricks).

In 2015 Mondal and Pramanik [97] defined a refined tangent similarity measure strategy of refined neutrosophic sets andproved 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 MADM strategies based on interval rough cosine, Dice and Jaccard similarity measures and presented an application, 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 novel MADM strategy for dealing with MADM problems in rough tri-complex neutrosophic envioronment. They presented comparison with other existing rough neutrosophic similarity measures.

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 setenvironment. They presented a hypothetical application tothe 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 stduy Mondal et al. [99] developed a novel MADMstrategies to solve MADM problems in rough neutrosophic environment. They provided an application, namely selection of the most suitable smart phone for rough use. They also presented comparison between the obtained results from the three MADM strategies based on the three rough neutrosophic similarity measures.

In 2017, Mondal, Pramanik and Smarandache [100] developed a new MAGDM strategy by extending the TOPSIS strategy in rough neutrosphic environment, calledrough neutrosophic TOPSIS strategy for MAGDM. Theyalso proposed rough neutrosophic aggregate operator and rough neutrosophic weighted aggregate operator. Finally, they presented a numerical example to demonstrate the applicability and effectiveness of proposed TOPSIS startegy.

Mondal, Pramanik, Giri and Smarandache [101] proposed NNHMO and NNWHMO and cosine function to determine unknown criteria weights in neutrosophic number (NN) environment. They developed two strategies of ranking NNs based on score function and accuracy function. They also developed two novel MCGDM strategies based on the proposed aggregation operators. They 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 this 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).

They 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).

They defined compromise function to determine unknown weights of the attributes in SVNS environment. They developed a novel MADM strategy based on the proposed weighted similarity measure. Lastly, they solved a numerical problem and compared the obtained results with other 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. They also developed a novel MADM sgtrategy based on the proposed tangent similarity measure in interval valued neutrosophic environment. They also presented a numerical example namely, selection of the best investment sector for an Indian government employee. Tthey also presented a comparative analysis.

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

Mr. Kalyan Mondal is a young and hardworking researchers 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 international level.

According to "*Researchgate*'', citation of his research exceeds 365.

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 (GRA) strategy for MADM problem with single valued neutrosophic attribute values. In neutrosophic environment, this the first case where GRA was applied to solve MADM problem in neutrosophic environment. The authros 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 multiple attribute decision making problem 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 of the proposed strategy and to demonstrate its practicality and effectiveness.

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 number.

In 2015, Biswas et al. [107] extended TOPSIS method 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 method MAGDM in single-valued neutrosophic environment. A non-linear programming based strategy is developed to study MAGDM problem. In the same study, all the rating values considered with SVNSs are converted in interval numbers. First, for each decision maker the relative closeness co-efficient intervals of alternatives are determined by using the nonlinear programming model. Then the closeness co-efficient intervals of each alternative are aggregated according to the weights of decision makers. Further a priority matrix is developed with the aggregated intervals of the alternatives and the ranking order of all alternatives is obtained 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 approach.

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 under 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 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 SVNHFS. The authors also defined positive ideal solution and negative ideal solution by score value and accuracy value. The authors calculated the GRA relation degree between each alternative and ideal alternative. The authors also determined a relative relational degree to obtain the ranking order of all alternatives by calculating the degree of GRA relation to both positive and negative ideal solutions. Finally, the authors provided an illustrative example to show the validity and effectiveness of the proposed approach .

Biswas et al. [112] introduced single-valued trapezoidal neutrosophic numbers(SVTrNNs), which is a special case of single-valued neutrosophic numbers and developed a ranking method for ranking SVTrNNs. The authors presented some operational rules as well as cut sets of SVTrNNs. The value and ambiguity indices of truth, indeterminacy, and falsity membership functions of SVTrNNs have been defined. 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 provied an illustrative example to demonstrate the validity and applicability of the proposed approach.

Biswas, Pramanik, and Giri [113] proposed a class of distance measures for single-valued neutrosophic hesitant fuzzy sets in 2016 and proved their properties with variational parameters. The authors appied weighted distance measures to calculate the distances between each alternative and ideal alternative in the MADM problems. The authors provided an illustrative example to verify the proposed approach and to show its fruitfulness.

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 SVTrNN and established some of their properties. The authors developed a ranking method with the proposed indexes to rank SVTrNN. The authors developed a new strategy to solve MADM problems in SVTrNN environment.

Dr. Pranab Biswas is a young and hardworking researchers in neutrosophic field. 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 System’’ in 2018. According to “*Researchgate*’’, citation of his research exceeds 365. Research papers of Biswas et al. [105, 112] received the best paper award from Neutrosophic Sets and System 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: is “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 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 [115] introduced refined tangent similarity measure.The authors presented 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 exampleof teacher selectionin in neutrosophic refined set environment to see the effectiveness of the proposed strategy.

In 2016, Banerjee et al. [116] developed TOPSIS startegy for MADM in refined neutrosophic environment. The main thing in this paper is that Euclidean distances from positive ideal solution and negative ideal solution are calculated to construct relative closeness coefficients. The authors also provied a numerical example to show the feasibility and applicability of the proposed TOPSIS strategy.

In 2017, Banerjee, Pramanik, Giri [117] at first developed MADM in neutrosophic cubic set environment using GRA In this paper, the authors discussed about positive and negative GRA coefficients ,and weighted GRA coefficients, Hamming distances for weighted GRA coefficients and standard GRA coefficient.

Banerjee and Pramanik [118] established single-objective linear goal programming problem with Smarandache neutrosophic numbers (SNNs).
In the same study, Banerjee and Pramanik [118] developed three goal programming models with SNN. The authors provided comparision between the proposed goal propramming strategy and existing strategy in the literature.
Pramanik and Banerjee [119] also developed three goal programming models for multi-objective programming problem with SNNs.
Her Ph. D. thesis [120] entilted: is "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 50.

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 multi criteria decision making . 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 [121] 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 [122] 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 [123] defined IN-cross entropy measure in INS environment in 2017. They proved the basic properties of the cross entropy measure. They 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, they solved a MAGDM problem to show the feasibility and efficiency of the proposed MAGDM strategy.

Pramanik, Dalapati, Alam, and Roy [124] defined TODIM strategy in bipolar neutrosophic set environment to handle MADGDM. They proposed a new strategy for solving MAGDM problems. They also solved an MADM problem to show the applicability and effectiveness of the proposed startegy. nd accuracy functions. At first they develop

Dalapati.et al. [125] introduced the score and accuracy functions for neutrosophic cubic sets and prove their basic properties in 2017. They developed a strategy for ranking of neutrosophic cubic numbers based on the score and accuracy functions. They first developed a TODIM (Tomada de decisao interativa e multicritévio) in the neutrosophic cubic set (NC) environment.They also established a new NC-TODIM strategy. They also solved a MAGDM problem to show the applicability and effectiveness of the developed strategy. Lastly, they conducted a comparative study to show the usefulness of proposed strategies.

In 2018 Dalapati et al. [126] extended the traditional VIKOR strategy to NC-VIKOR strategy and developed a NC-VIKOR based MAGDM in neutrosophic cubic set environment. They defined the basic concept of neutrosophic cubic set . Then, they introduced neutrosophic cubic numbers weighted averaging operator and applied it to aggregate the individual opinion to one group opinion. They presented a NC-VIKOR based MAGDM strategy with neutrosophic cubic set and a sensitivity analysis. Finally,they solved a MAGDM problem to show the feasibility and efficiency of the proposed MAGDM strategy.

Dalapati et al. [127] extended the VIKOR strategy to MAGDM with bipolar neutrosophic environment. They presented the basic concept of bipolar neutrosophic set. They introduced bipolar neutrosophic numbers weighted averaging operator and applied it to aggregate the individual opinion to one group opinion. They proposed a VIKOR based MAGDM strategy with bipolar neutrosophic set. Lastly, they solved a MAGDM problem to show the feasibility and efficiency of the proposed MAGDM strategy and present a sensitivity analysis.

Pramanik, Dalapati, Alam, and Roy [128] 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). They proved some theorems on neutrosophic cubic soft sets.They also discuss various approaches of Internal Neutrosophic Cubic Soft Sets (INCSSs) and external neutrosophic cubic soft sets (ENCSSs) and also investigate some of their properties.

Pramanik, Dalapati, Alam, Smarandache, and Roy [129] defined a new cross entropy measure in SVNS environment.They also proved the basic properties of the NS cross entropy measure. They defined weighted SN-cross entropy measure and proved its basic properties. At first they proposed MAGDM strategy based on NS- cross entropy measure.

Pramanik, Dalapati, Alam, Roy, Smarandache [130] defined similarity measure between neutrosophic cubic sets and proved its basic properties. They developed a new MCDM strategy basd on the proposed similarity measure. They also provided an illustrative example for MCDM strategy to show its applicability and effectiveness.

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.

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 [131] discussed about application of game theory to Jammu Kashmir conflict between India and Pakistan. Pramanik and Roy [20] extended the concept of game theoretic model of the Jammu and Kashmir conflict in neutrosophic environment.

At first, Roy and Das [132] 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 multi-objective neutrosophic optimization technique and its application to structural design in 2016.

In 2017, Roy and Sarkar [133-136] also presented several applications of neutrosophic optimization technique.

In 2017, Pramanik, Roy, Roy, and Smarandache [137] presented multi criteria decision making (MCDM) using correlation coefficient under rough neutrosophic environment. They 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 [138] 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 [139] 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 [122-130, 137-139] with S. Pramanik, S. Dalapati, S. Alam and Rumi Roy.

Prof. Roy is a great motivator and very hardworking personality. According to “Googlescholar” his research gets citation over 2635.

3.7 Prof. Bibhas C. Giri

Prof. Bibhas C.Giri is a Prof. of mathematics in Jadavpur University. He works on supply chain management, logistics, operations research, neutrosophic decision making, etc.

Contribution:

Prof. Biswas works with S. Pramanik, P. Biswas adn P. P. Dey in neutrosophic environment. His paper coauthoired with Kalyan Mondal and Surapati Pramanik received outstanding paper award in West Bengal State Science Technology Congress, 2018. His works can be found in the research works [71-80, 82, 101-117].
Prof. Giri is a great motivator. According to “*Googlescholar*’’, his research receives more than 4600 citations.

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 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 on topology, Fuzzy set theory, Rough sets, soft sets, neutrosophic set, neutrosophic soft set, etc.

Contribution:

In 2014 Anjan Mukherjee and Sadhan Sarkar [140] defined the Hamming and Euclidean distances between two interval valued neutrosophic soft sets (IVNS sets) and they also introduced similarity measures based on distances between two interval valued neutrosophic soft sets. They proved some basic properties of the similarity measures between two interval valued neutrosophic soft set. They establ;ished a decision making strategy for interval valued neutrosophic soft set setting using similarity measures between IVNS sets

Mukherjee and Sarkar [141] also defined several distances between two interval valued neutrosophoic soft sets in 2014. They proposed similarity measure between two interval valued neutrosophic soft sets. They 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 [142] defined several distances between two neutrosophoic soft sets. They also defined similarity measure between two neutrosophic soft sets. They developed a decision making strategy based onthe proposed similarity measure.

Mukherjee and Sarkar [143] 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 and existing strategies introduced by Mukherjee and Sarkar[142]. The authors found that the proposed strategy 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 in neutrosophic decision making was evaluated by Prof. Anjaan Mukherjee. Research of Prof. Mukherjee receives more than 700 citations.

3.9 Dr.Pabitra Kumar Maji

Dr.Pabitra kumar Maji 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 [144] presented an application of neutrosophic soft set in object recognition problem based on multi-observer input data set. He also introduced an algorithm to choose an appropriate object from a set of objects depending on some specified parameters.

In 2014, Maji, Broumi, Smarandache [145] 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 ,they defined the product of two intuitionistic neutrosophic soft set over ring.

In 2015, Maji [146] discussed weighted neutrosophic soft sets. He presented an application of weighted neutrosophic soft sets in MCDM problem. According “Googlescholar’’, his publication includes 20 research paper having citations 5948.

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 [147] 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 decision-making strategy based on the proposed operators and presented an illustrative numerical example.

In 2017, Garg and Nancy [148] developed a non-linear programming (NP) model based on TOPSIS to solve decision-making problems. The authors also mention their importance are in the form of interval neutrosophic numbers (INNs). At first, the authors constructed 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 [149] defined some new types of distance measures, overcoming 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 its validity. The authors also demonstrated the defined measures with case studies of pattern recognition as well as medical diagnoses.
Dr. Garg research receives more than 1850 citations.

3.11 Dr. Sukanto Bhattacharya

Sukanto Bhattacharya is associated with Deakin Business School, Deakin University.

Sukanto Bhattacharya [150] is the first researchers 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 neutrosophic notion of perceived risk and the entropic utility measure.
Prof. Bhattacharya is an active researcher and his work in neutrosophics can be found in [150, 151, 152, 153]. His research receives more than 380 citations.

Conclusions

We have presented a brief overview of the contributions of some selected Indian researchers who conducted research in neutrosophics. We briefly presented the contribution of the selected Indian neutrosophic researchers in MADM. In future, the contribution of other Indian researchers such as W. B. V. Kandasamy, Majumdar Surapati Pramanik, Samarjit Kar, and others in developing neutrosophics can be studied. Decision making in neutrosophic hybrid environment is gaining much attention. So it is a promising field of research in different neutrosophicnhybrid environment and the real cahllenge lies in the applications of the developed theories.

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