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INTERVAL VALUED PENTAPARTITIONED NEUTROSOPHIC GRAPHS WITH AN APPLICATION TO MCDM

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Abstract: *The concept of interval valued pentapartitioned neutrosophic set is the extension of interval-valued neutrosophic set, quadripartitioned neutrosophic set, interval valued quadripartitioned neutrosophic set and pentapartitioned neutrosophic set. The powerful mathematical tool known as the interval valued pentapartitioned neutrosophic set divides indeterminacy into three separate components: unknown, contradiction, and ignorance. There are several applications for graph theory in everyday life, and it is a rapidly growing topic. The concept of an interval valued pentapartitioned neutrosophic set is used in graph theory. A decision-making method multicriteria (MCDM) is proposed by using the developed Interval valued Pentapartitioned Neutrosophic set with a numerical illustration. In this paper, as an extension of interval valued neutrosophic graph theory, we introduce the notions of Interval-Valued Pentapartitioned Neutrosophic Graph (IVPPN-graph) with degree, size, and order of an IVPPN-graph.*

Key words*: Neutrosophic Set, Interval valued Pentapartitioned Neutrosophic sets, Neutrosophic Graph, IVPPN-Graph.*

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1. Introduction

Linguistic variables with uncertainties such as vagueness, imprecision and ambiguity are handled with a special type of mathematical tool known as fuzzy set theory (Zadeh, 1965). The contribution of research articles in the field of fuzzy sets in mathematics and wide range of applications are growing exponentially. The advantage of introducing Zadeh's fuzzy sets in the place of classical sets has been its accuracy and precision in theory and compatibility and efficiency in case of applications.

Fuzzy set has been extended to Intuitionistic fuzzy set (Atanasov, 1986). in which the membership and non-membership degree of the element of that set ranges between 0 and 1. Intuitionistic set was further extended to Interval valued fuzzy sets, Neutrosophic sets, Pythagorean sets and so on. (Smarandache,1999 &2020) presented a new type of set as an extension of intuitionistic fuzzy set which is called Neutrosophic set. A neutrosophic set is characterized by a truth membership degree (T), an indeterminacy membership degree (I) and a falsity membership degree (F) independently, which are within the real unit interval]0-,1+[satisfying the condition that the total of the membership grades is within the range of 0 to 3. In (Wang, 2010) single valued neutrosophic set (SVNS) with set-theoretic operators was investigated by Wang et al. SVNSs have been developed into many new concepts and are applied in different disciplines (Broumi et al., 2016 & 2016a & 2016b &2016c; Chatterjee et al., 2016&2016b). Pythagorean set (Yager, 2013). is an extension of the intutionistic set in which the condition differs from the intutionistic set that the sum of the squares the membership is less than 1.

By combining the idea of fuzzy graphs and Pythagorean neutrosophic set Ajay and Chellamani et al. presented Pythagorean neutrosophic graphs (Ajay & Chellamani, 2020) is a combination of the Pythagorean and Neutrosophic set in which the the sum of the squares of the membership, non-membership and indeterminacy membership lies in [0,2] and further theoretical concepts were developed in (Ajay & Chellamani, , 2021 ; Chellamani & Ajay, 2021; Ajay et al., 2021 , 2022 ,2020a) ; Chellamani et al.,2021). The partition of indeterminacy function of the neutrosophic set into contradiction part and ignorance part is defined as the quadripartitioned single-valued neutrosophic set (Chatterjee et al., 2016, 2020)

(Quek et al, 2022) introduced the notion of pentapartitionned neutrosophic graphs (PPNGs), as an extended version of Single valued neutrosophic graphs. (Mallick & Pramanik, 2020) proposed the concept of interval-valued pentapartitionned neutrosophic sets (IVPPNSs) as a generalization of pentapartitionned neutrosophic sets in the spirit of interval-valued neutrosophic sets (Broumi, 2016) The concept of Interval valued pentapartitioned neutrosophic sets (IVPPNSs) allows a decision-making expert to represented the membership degree contradiction membership function $C_A(x)$, an unknown membership function $U_A(x)$ and a falsity membership degree of a set of options in terms of the interval; hence, the range of uncertain information they can describe is widened. Interval-valued pentapartitioned neutrosophic numbers (IVPPNNs) are the generalized version of pentapartitioned neutrosophic numbers, quadripartitioned neutrosophic numbers, interval-valued quadripartitioned neutrosophic numbers. IVPPNNs will help model problems with incomplete, uncertain and indeterminate information. And further theoretical concepts were developed in (Das et al, 2022& 2022a; Pramanik, 2022). (Hussain et al, 2022) introduced the notion of quadripartitioned single-valued neutrosophic graphs and developed some operations on it. The Cartesian product, cross product, lexicographic product, strong product and composition of quadripartitioned single-valued neutrosophic graph have been investigated. The proposed concepts are illustrated with an application in the climatic analysis of apple cultivation. (Kaufmann, 1973), based on fuzzy relation (Zadeh, 2020). developed the idea of fuzzy graphs (FGs). Later, (Rosenfeld, 1975) defined the basic properties of fuzzy relations which are generalized with fuzzy set as a base set and fuzzy analogues of graphic theoretical concepts like bridges and trees were established with their properties and further fuzzy graph concepts were developed and applied in the real life situations in (Mohamed et al., 2020; Mordeson & Chang-Shyh, 1994; Naz et al, 2017 &2018; Quek, et al., 2018 ; Smarandache, 2013 ; Tan et al., 2021 ; Das et al., 2021 ; Majumder et al, 2021; Saha et al., 2022). Recent developments of the fuzzy extensions are developed as in (Kumar et al., 2019 ; Radha et al.,2021 ; Vellapandi & Gunasekaran, 2020 ;Das & Edalatpanah, 2020 ; Polymenis, 2021; Mao et al, 2020 ; Voskoglou & Broumi, 2022 ; Zhang et al., 2022 ; Al-Hamido, 2022). To the best of authors knowledge, a very less work is being done on the interval-valued pentapartitioned neutrosophic set (IVPPNS), so the present study define the operations on the IVPPNS and later on extend it to graphs environment. The major contributions in this work are explained as follows:

1. The notions of interval valued pentapartitioned neutrosophic Graphs (IVPPNGs) are introduced. This manuscript makes the first attempt in the literature about the concept in neutrosophic graphs.

2. In addition, the complete and strong IVPPNG are defined. The operations like a Cartesian product, cross product, lexicographic product, strong product and the composition of IVPPNGs with their properties are discussed.

3. In addition, the complete, strong and complement of IVPPNGs are defined.

4. We extend some of the basic properties for this PNFG along with few examples. We have developed a decision-making model using the introduced Interval valued Pentapartitioned Neutrosophic graphs and applied it for a numerical illustration. A list of contribution (Table 1) of authors is presented below.

Table 1. Contribution of authors to extension of neutrosophic graphs

Authors	Year	Contributions
Akram and Siddique	2017	Introduced neutrosophic competition graph
Broumi et al.	2018	Introduced Generalized neutrosophic graph
Das et al	2020	Introduced generalized neutrosophic competition graph
Ajay and Chellamani	2020	Pythagorean Neutrosophic Fuzzy Graphs
S. Satham Hussain	2022	Quadripartitioned Neutrosophic Soft Graphs
S. Satham Hussain	2022	Quadripartitioned Bipolar Single Valued Neutrosophic Graph
S. Satham Hussain	2022	Quadripartitioned Single-Valued Neutrosophic Graph
Quek et al.	2022	Pentapartitioned Single-Valued Neutrosophic Graph
Our approch	2022	Interval valued Pentapartitioned Single-Valued Neutrosophic Graph

2. Preliminaries

This section summarizes some basic concepts from the theory of IVNSs and the concept of IVPPNSs, which is the foundation for the concept of IVPPNGs. Further details on the NS, SVNS and IVNS theories can be found in [3-6] Smarandache (1999) and (Wang et al. 2010), respectively.

Definition 2.1: [5] Let A and B be two SVNSs over a universe Y.

(i) A is contained in B, if $T_A(y) \le T_B(y)$, $I_A(y) \ge I_B(y)$, and $F_A(y) \ge F_B(y)$, for all $y \in$ Y . This relationship is denoted as A ⊆ B (1)

(ii) A and B are said to be equal if A ⊆ B and B ⊆ A (2)

(iii) A^c = (y, ($F_A(y)$, 1 − $I_A(y)$, $T_A(y)$)), for all $y \in$ Y (3)

(iv) A ∪ B = (y, (max (T_A, T_B), min (I_A, I_B), min (F_A, F_B))), for all $y \in$ Y. (4)

(v) A ∩ B = (y, (min (T_A, T_B), max (I_A, I_B), max (F_A, F_B))), for all $y \in$ Y. (5)

Definition 2.2: (Wang et al, 2010) An Interval valued neutrosophic Sets (IVNS) A in X is denoted by an interval truth-membership function $T_A(x)$, an interval indterminacy-membership function $I_A(x)$,and an interval falsity membership function $F_A(x)$ for each point x in X, there are

$\tilde{T}_A(x) = [T_A^L(x), T_A^U(x)] \subseteq [0,1],$ (6)

$\tilde{I}_A(x) = [I_A^L(x), I_A^U(x)] \subseteq [0,1],$ (7)

$\tilde{F}_A(x) = [F_A^L(x), F_A^U(x)] \subseteq [0,1].$ (8)

Therefore an IVNS ***A*** can be denoted as, A= $\{\langle x, \tilde{T}_A(x), \tilde{I}_A(x), , \tilde{F}_A(x)\rangle |\ x \in X\}$

Then the sum of $\tilde{T}_A(x), \tilde{I}_A(x), \tilde{F}_A(x)$ satisfies the condition

$0 \le T_A^U(x) + I_A^U(x) + F_A^U(x) \le 3$ (9)

If the upper and lower ends of the interval values of $T_A(x), I_A(x)$ *and* $F_A(x)$ in an IVNS are equal then IVNS reduces to the SVNS.

Definition 2.3: (Wang et al, 2010) Let A and B be two IVNSs over a universe Y .

(i) A is contained in B, if $T_A^L(y) \le T_B^L(y), T_A^U(y) \le T_B^U(y)$, $I_A^L(y) \ge I_B^L(y), I_A^U(y) \ge I_B^U(y)$, and $F_A^L(y) \ge F_B^L(y), F_A^U(y) \ge F_B^U(y)$, for all $y \in$ Y. This relationship is denoted as

A ⊆ B. (10)

(ii) A and B are said to be equal if A ⊆ B and B ⊆ A. (11)

(iii) A^c = (y, ($F_A(y)$, 1 − $I_A(y)$, $T_A(y)$)), for all $y \in$ Y. (12)

(iv) A ∪ B = (y, (max(T_A, T_B), min(I_A, I_B), min(F_A, F_B))), for all $y \in$ Y. (13)

(v) A ∩ B = (y, (min(T_A, T_B), max(I_A, I_B), max(F_A, F_B))), for all $y \in$ Y (14)

Definition 2.4: (Chatterjee eta al., 2016) **Quadripartitioned neutrosophic sets**

Let X be a universe. A Quadripartitioned neutrosophic set A with independent neutrosophic components on X is an object of the form

$A = \{< x, T_A(x), C_A(x), U_A(x), F_A(x) >: x \in$ X} (15)

$$and\ 0 \leq T_A(x) + C_A(x) + U_A(x) + F_A\,(x) \leq 4 \tag{16}$$

Here, $T_A(x)$ is the truth membership, $C_A(x)$ is contradiction membership, $U_A(x)$ is ignorance membership and $F_A(x)$ is the false membership.

Definition 2.5: (Pramanik, 2022). **Interval quadripartionned neutrosophic Sets**

An Interval quadripartionned neutrosophic Sets (IQNS) A in X is denoted by truth-membership function $T_A(x)$, a contradiction membership function $C_A(x)$, an unknown membership function $U_A(x)$ and a falsity membership function $F_A(x)$, for each point x in X, there are

$T_A(x) = [T_A^L(x), T_A^U(x)] \subseteq [0,1]$, $C_A(x) = [C_A^L(x), T_A^U(x)] \subseteq [0,1]$,

$U_A(x) = [U_A^L(x), U_A^U(x)] \subseteq [0,1]$, $F_A(x) = [F_A^L(x), F_A^U(x)] \subseteq [0,1]$,

Therefore an IQNS $\boldsymbol{A}$ can be denoted as,

$$\text{A}= \{\langle x, T_A(x), C_A(x), U_A(x), F_A(x)\rangle |\ x \in X\} \tag{17}$$

$$\text{A}=\left\{\left\langle \begin{matrix} x,[T_A^L(x),T_A^U(x)],[C_A^L(x),T_A^U(x)] \\ [U_A^L(x),U_A^U(x)],[F_A^L(x),F_A^U(x)] \end{matrix}\right\rangle |\ x \in X\right\} \tag{18}$$

Then the sum of $T_A(x), C_A(x), U_A(x), F_A(x)$ satisfies the condition

$$0 \leq T_A^U(x) + C_A^U(x) + U_A^U(x) + F_A^U(x) \leq 4 \tag{19}$$

If the upper and lower bounds of the interval values of $T_A(x), C_A(x), U_A(x)\ and\ F_A(x)$ in an IQNS are equal then IQNS reduces to the QSVNS.

Definition 2.6: (Mallick & Pramanik, 2020). **Pentapartitioned neutrosophic sets**

Let X be a universe. A Pentapartitioned neutrosophic set A with independent neutrosophic components on X is an object of the form

$$A = \{< x, T_A(x), C_A(x), U_A(x), G_A(x), F_A(x) >: x \in \text{X}\} \tag{20}$$

$$and\ 0 \leq T_A(x) + C_A(x) + U_A(x) + G_A(x) + F_A\,(x) \leq 5 \tag{21}$$

Here, $T_A(x)$ is the truth membership, $C_A(x)$ is contradiction membership, $U_A(x)$ is ignorance membership, $G_A(x)\ is$ ignorance membership, and $F_A(x)$ is the false membership.

Definition 2.7: (Das et al., 2022) **Interval Pentapartionned neutrosophic sets**

An Interval Pentapartionned neutrosophic Sets (IPNS) A in X is denoted by truth-membership function $T_A(x)$, a contradiction membership function $C_A(x)$, an unknown membership function $U_A(x)$, $G_A(x) is$ ignorance membership and a falsity membership function $F_A(x)$ for each point x in X, there are

$T_A(x) = [T_A^L(x), T_A^U(x)] \subseteq [0,1]$, $C_A(x) = [C_A^L(x), T_A^U(x)] \subseteq [0,1]$,

$U_A(x) = [U_A^L(x), U_A^U(x)] \subseteq [0,1]$, $G_A(x) = [G_A^L(x), G_A^U(x)] \subseteq [0,1]$,

$F_A(x) = [F_A^L(x), F_A^U(x)] \subseteq [0,1]$,

Therefore an IPNS $\boldsymbol{A}$ can be denoted as,

$$\text{A}= \{\langle x, T_A(x), C_A(x), U_A(x), G_A(x), F_A(x)\rangle |\ x \in X\} \tag{22}$$

$$A=\left\{\langle \frac{x,[T_A^L(x),T_A^U(x)],[C_A^L(x),T_A^U(x)]}{[U_A^L(x),U_A^U(x)],[G_A^L(x),G_A^U(x)],[F_A^L(x),F_A^U(x)]}\rangle \mid x \in X\right\}$$

Then the sum of $T_A(x), C_A(x), U_A(x), G_A(x), F_A(x)$ satisfies the condition

$$0 \le T_A^U(x) + C_A^U(x) + U_A^U(x) + G_A^U(x) + F_A^U(x) \le 5 \tag{23}$$

If the upper and lower bounds of the interval values of $T_A(x), C_A(x), U_A(x), G_A(x)$ *and* $F_A(x)$ in an IPNS are equal then IPNS reduces to the PSVNS.

Definition 2.8: (Broumi et al., 2016) Let V be a set. Let E $\subseteq \{\{\mu, v\}: \mu, v \in V \text{ with } \mu \ne v\}$.

Let A be an IVNS on V and B be an IVNS on E with

$$T_B^l(\mu, v) \le \min\{T_A^l(\mu), T_A^l(v)\}, T_B^u(\mu, v) \le \min\{T_A^u(\mu), T_A^u(v)\} \tag{24}$$

$$I_B^l(\mu, v) \ge \max\{I_A^l(\mu), I_A^l(v)\}, I_B^u(\mu, v) \ge \max\{I_A^u(\mu), I_A^u(v)\} \tag{25}$$

$F_B^l(\mu, v) \ge \min\{F_A^l(\mu), F_A^l(v)\}, F_B^u(\mu, v) \ge \min\{F_A^u(\mu), F_A^u(v)\}$for all $\{\mu, v\}\in$ E. Then G=(A, B, V, E) is said to be an Interval-valued neutrosophic graph. (26)

Definition 2.9: [22] Let V be a set. Let $E\subseteq \{\{v, \omega\}: v, \omega \in V' \text{ with } \mu \ne v\}$. Let A be a PPNS on V, and B be a PPNS on E, with $t_B(\mu, v) \le \min\{t_A(\mu), t_A(v)\}$, $c_B(\mu, v) \ge \max\{c_A(\mu), c_A(v)\}$, $g_B(\mu, v) \ge \max\{g_A(\mu), g_A(v)\}$, $u_B(\mu, v) \ge \max\{u_A(\mu), u_A(v)\}$and $f_B(\mu, v) \ge \max\{f_A(\mu), f_A(v)\}$for all $\{\mu, v\}\in$ E. Then we have the following:

(i) G=(A, B, V, E) is said to be a pentapartitioned neutrosophic graph (PPNG).

(ii) Each $v \in$ V is said to be a vertex of G.

(iii) Each$\{\mu, v\}\in$ E is said to be an edge of G.

3. Interval Pentapartitioned neutrosophic graphs

In this section, first the concept of interval pentapartitioned neutrosophic graphs (IVPPNGs) is introduced. Then based on the definitions of IVNS, interval-valued neutrosophic graphs [24] and IVPPNS given in definition 2.6 and definition 2.7, respectively will be used to put forward the novel concept of IVPPNGs. The related properties pertaining to this concept will be subsequently investigated.

Definition 3.1. Let V be a set. Let $E\subseteq \{\{\mu, v\}: v, \mu \in V \text{ with } \mu \ne v\}$. Let A be an IVPPNS on V, and B be an IVPPNS on E, with

$$t_B^l(\mu, v) \le \min\{t_A^l(\mu), t_A^l(v)\}, t_B^u(\mu, v) \le \min\{t_A^u(\mu), t_A^u(v)\}, \tag{27}$$

$$c_B^l(\mu, v) \ge \max\{c_A^l(\mu), c_A^l(v)\}, c_B^u(\mu, v) \ge \max\{c_A^u(\mu), c_A^u(v)\}, \tag{28}$$

$$g_B^l(\mu, v) \ge \max\{g_A^l(\mu), g_A^l(v)\}, g_B^u(\mu, v) \ge \max\{g_A^u(\mu), g_A^u(v)\}, \tag{29}$$

$$u_B^l(\mu, v) \ge \max\{u_A^l(\mu), u_A^l(v)\}, u_B^u(\mu, v) \ge \max\{u_A^u(\mu), u_A^u(v)\}, \tag{30}$$

and $f_B^l(\mu, v) \ge \max\{f_A^l(\mu), f_A^l(v)\}, f_B^u(\mu, v) \ge \max\{f_A^u(\mu), f_A^u(v)\},$ (31)

for all $\{\mu, v\}\in$ E. Then we have the following:

(i) G=(A, B, V, E) is said to be an interval pentapartitioned neutrosophic graph (IVPPNG). (32)

(ii) Each $v \in$ V is said to be a vertex of G. (33)

(iii) Each{ μ, v }∈ E is said to be an edge of G. (34)

Fig. 1 A graphical representation of the PPNG *G.*

Notation 3.1.1 Let G = (A, B, V, E) be a IVPPNG. Denote m_A : V → $[0, 1]^5$, where $m_A(v)$=($\tilde{t}_A(v)$, $\tilde{c}_A(v)$, $\tilde{g}_A(v)$, $\tilde{u}_A(v)$, $\tilde{f}_A(v)$) for all $v \in$ V. Denote m_B: E →Int($[0, 1]^5$), where $m_B(\mu, v)$ =($\tilde{t}_B(\mu, v)$, $\tilde{c}_B(\mu, v)$, $\tilde{g}_B(\mu, v)$, $\tilde{u}_B(\mu, v)$, $\tilde{f}_B(\mu, v)$) for all { μ, v } ∈ E.

Example 3.2 Let G = (A, B, V, E) be an IVPPNG with V = {v_1, v_2, v_3, v_4, v_5} and E = {{v_1, v_2}, {v_1, v_3}, {v1,v4}, {v_2, v_5}, {v_4, v_5}}. Then we have the following (Fig. 1):

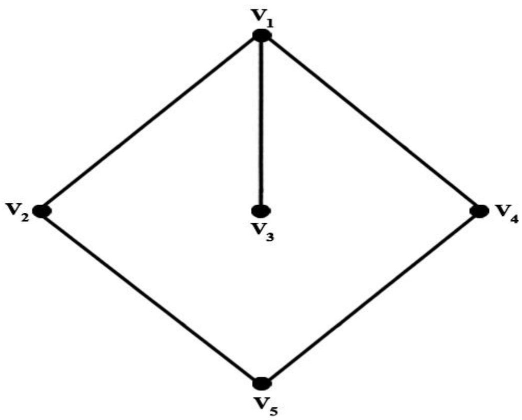


Figure 1. Interval Valued Pentapartitioned Neutrosophic Graph

$m_A(v_1) = ([.7,.9], [.6,.7], [.5,.7], [.4,.6], [.3,.5])$,

$m_A(v_2) = ([.6,.7], [.5,.8], [.3,.6], [.4,.9], [.1,.5])$,

$m_A(v_3) = ([.4,.8], [.5,.7], [.6,.9], [.7,.9], [.2,.5])$,

$m_A(v_4) = ([.3,.6], [.4,.7], [.5,.9], [.7,.9], [.2,.5])$,

$m_B(v_5) = ([.7,.9], [.6,.8], [.5,.7], [.3,.6], [.2,.5])$.

$m_B(v_1 v_2) = ([.6,.7], [.7,.9], [.5,.7], [.5,.9], [.4,.6])$,

$m_B(v_1 v_3) = ([.4,.8], [.6,.8], [.6,.9], [.4,.6], [.3,.6])$,

$m_B(v_1 v_4) = ([.3,.6], [.6,.8], [.5,.9], [.7,.9], [.3,.5])$,

$m_B(v_2 v_5) = ([.6,.7], [.6,.8], [.5,.7], [.4,.9], [.2,.6])$,

$m_B(v_4 v_5) = ([.3,.6], [.6,.8], [.5,.9], [.7,.9], [.3,.7])$.

Definition 3.3. Let G = (A, B, V, E) and H = (A', B', V', E') be two IVPPNGs that satisfies the following conditions:

(i) $V' \subseteq$ V (35)

(ii) $E' \subseteq \{\{v, \mu\}: v, \mu \in V' \ with\ \mu \neq v\}$ (36)

(iii) $m_{A'}(v)= m_A(v)$, for all $v \in V' \subseteq$ V (37)

(iv) $m_{B'}(v, \mu)=m_B(v, \mu)$, for all $\{v, \mu\} \in E' \subseteq$ E. (38)

Then, H is said to be a partial *interval valued pentapartitioned neutrosophic graph* (partial-IVPPNG) of G.

Definition 3.4. Let G = (A, B, V, E) and H = (A', B', V', E') be two IVPPNGs that satisfies the following conditions:

(i) $V' \subseteq$ V (39)

(ii) $E' \subseteq \{\{v, \omega\}: v, \omega \in V' \ with\ \omega \neq v\}$ (40)

(iii) $t^l_{A'}(v) \leq t^l_A(v), t^u_{A'}(v) \leq t^u_A(v), c^l_{A'}(v) \geq c^l_A(v), c^u_{A'}(v) \geq c^u_A(v), g^l_{A'}(v) \geq g^l_A(v), g^u_{A'}(v) \geq g^u_A(v), u^l_{A'}(v) \geq u^l_A(v), u^u_{A'}(v) \geq u^u_A(v), f^l_{A'}(v) \geq f^l_A(v), f^u_{A'}(v) \geq f^u_A(v)$ for all $v \in V' \subseteq$V (41)

(iv) $t^l_{B'}(v, \omega) \leq t^l_B(v, \omega)$, $t^u_{B'}(v, \omega) \leq t^u_B(v, \omega)$, $c^l_{B'}(v, \omega) \geq c^l_B(v, \omega)$, $c^u_{B'}(v, \omega) \geq c^u_B(v, \omega)$, $g^l_{B'}(v, \omega) \geq g^l_B(v)$, $g^u_{B'}(v, \omega) \geq g^u_B(v, \omega)$, $u^l_{B'}(v, \omega) \geq u^l_B(v, \omega)$, $u^u_{B'}(v, \omega) \geq u^u_B(v, \omega)$, $f^l_{B'}(v, \omega) \geq f^l_B(v, \omega)$, $f^u_{B'}(v, \omega) \geq f^u_B(v, \omega)$, for all $\{ v, \omega \} \in E' \subseteq$ E. (42)

Then, H is said to be an interval valued pentapartitioned neutrosophic subgraph (IVPPNSG) of G.

Example 3.5. Let G_1be an IVPPNG and H_1, H_2 be the partial-IVPPNG and IVPPNSG of G_1, respectively. The graphical representation of G_1, H_1 and H_2 are shown in Figs. 2, 3 and 4, respectively. Here H_2 is a IVPPNSG of G_1 but not a partial-IVPPNG of G_1.

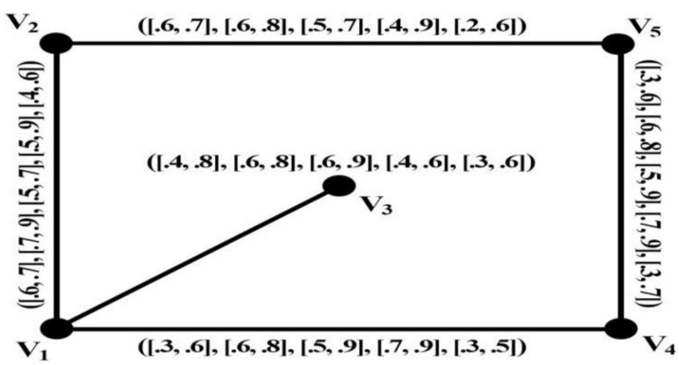
$m_A(v_1) = ([.7, .9], [.6, .7], [.5, .7], [.4, .6], [.3, .5])$,

$m_A(v_2) = ([.6, .7], [.5, .8], [.3, .6], [.4, .9], [.1, .5])$,

$m_A(v_3) = ([.4, .8], [.5, .7], [.6, .9], [.7, .9], [.2, .5])$,

$m_A(v_4) = ([.3, .6], [.4, .7], [.5, .9], [.7, .9], [.2, .5])$,

$m_B(v_5) = ([.7, .9], [.6, .8], [.5, .7], [.3, .6], [.2, .5])$.



G_1

Figure 2. Interval Valued Pentapartitioned Neutrosophic Graph

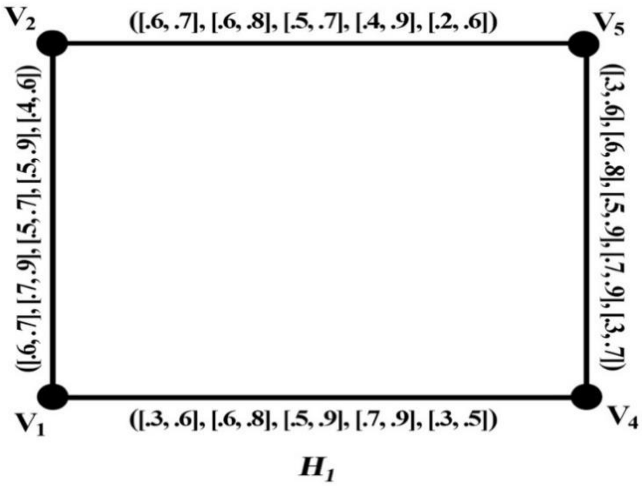


Figure 3. Partial Interval Valued Pentapartitioned Neutrosophic Graph

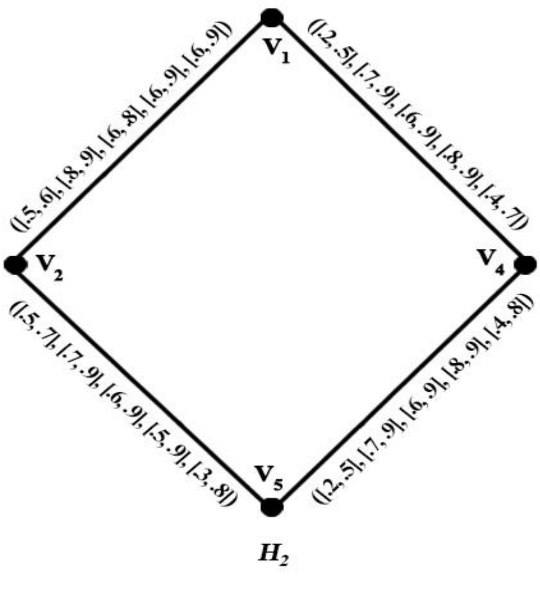


Figure 4. Interval Valued Pentapartitioned Neutrosophic Subgraph

Definition 3.6. Let G = (A, B, V, E) be an IVPPNG. Let v_0, v_1,..., v_n ∈ V , with {v_i, v_{i+1}} ∈ E for all 0 < i ≤ n-1, and with $v_i \neq v_j$ for all 0 ≤ i < j ≤ n-1. Then we have the following:

P =(v_0, v_1,..., v_n) is said to be a an interval valued pentapartitioned neutrosophic path (IVPPNP) in G.

For each i, {v_i, v_{i+1}} is said to be an *edge* of P.

n is said to be the *length* of P.

Definition 3.7. Let G = (A, B, V, E) be an IVPPNG. Then G is said to be *connected* if there exists at least one $\{ v, \omega \} \in$ E for all $v \in$ V.

Definition 3.8. Let G =(A, B, V, E) be an IVPPNG. Then $v \in$ V is said to be *isolated* if $\{ v, \omega \} \notin /$ E for all $\omega \in$ V \ $\{ v \}$. the IVPPNG has v_1 as the isolated vertex.

Definition 3.9. Let G = (A, B, V, E) be an IVPPNG and let $v \in$ V. The degree of v, written as d(v), is defined as d(v) $=\sum_{\mu \in V\ with \{v,\omega\} \in E} m_B(v, \omega)$.

Remark 3.9.1. It follows that d$(v) \in [0, 1]^5$.

Example 3.10. In Fig. 3 under Eg. 3.5, the degree of the vertices are as follows.

d(v_1) = (0.5, 1.7, 1.5, 1.1, 1.2), d(v_3) =(0.6, 1.7, 1.7, 1.2, 1.2), d(v_4)= (0.5, 1.8, 1.6, 1.3, 1.6).

Definition 3.11. Let G =(A, B, V, E) be an IVPPNG and let P =$(v_0, v_1,..., v_n)$ be an IVPPNP in G. The strength of P, denoted as s(P), is defined as : s(P)=

$$\left(\left[s_{t_A^l}(P), s_{t_A^u}(P)\right], \left[s_{c_A^l}(P), s_{c_A^u}(P)\right], \left[s_{g_A^l}(P), s_{g_A^u}(P)\right], \left[s_{u_A^l}(P), s_{u_A^u}(P)\right], \left[s_{f_A^l}(P), s_{f_A^u}(P)\right]\right)$$

$$= (s_{\tilde{t}}(P), s_{\tilde{c}}(P), s_{\tilde{g}}(P), s_{\tilde{u}}(P), s_{\tilde{f}}(P)) \qquad (43)$$

where

$s_{t_A^l}(P)= min\{t_B^l(v_i, v_{i+1}): 0 \le i \le n-1\}$, $s_{t_A^u}(P)= min\{t_B^u(v_i, v_{i+1}) : 0 \le i \le n-1\}$,
$s_{c_A^l}(P)= max\{c_B^l(v_i, v_{i+1}) : 0 \le i \le n-1\}$, $s_{c_A^u}(P)= max\{c_B^u(v_i, v_{i+1}) : 0 \le i \le n-1\}$,
$s_{g_A^l}(P)= max\{g_B^l(v_i, v_{i+1}) : 0 \le i \le n-1\}$, $s_{g_A^u}(P)= max\{g_B^u(v_i, v_{i+1}) : 0 \le i \le n-1\}$,
$s_{u_A^l}(P)= max\{u_B^l(v_i, v_{i+1}) : 0 \le i \le n-1\}$, $s_{u_A^u}(P)= max\{u_B^u(v_i, v_{i+1}) : 0 \le i \le n-1\}$, and
$s_{f_A^l}(P)= max\{f_B^l(v_i, v_{i+1}) : 0 \le i \le n-1\}$, $s_{f_A^u}(P)= max\{f_B^u(v_i, v_{i+1}) : 0 \le i \le n-1\}$, Moreover, the *strength of connectedness* among the vertices *a, b* ∈ *V* in *G*, denoted as r_G(a, b), is defined as:

$$r_G(\mathrm{a,b})=\left(r_{\tilde{t},G}(\mathrm{a,b}), r_{\tilde{c},G}(\mathrm{a,b}), r_{\tilde{g},G}(\mathrm{a,b}), r_{\tilde{u},G}(\mathrm{a,b}), r_{\tilde{f},G}(\mathrm{a,b})\right) \text{ With} \qquad (44)$$

$r_{\tilde{t},G}(\mathrm{a,b}) = \left[r_{t_A^l,G}(\mathrm{a,b}), r_{t_A^u,G}(\mathrm{a,b})\right]$, $r_{\tilde{c},G}(\mathrm{a,b}) = \left[r_{c_A^l,G}(\mathrm{a,b}), r_{c_A^u,G}(\mathrm{a,b})\right]$
$r_{\tilde{g},G}(\mathrm{a,b}) = \left[r_{g_A^l,G}(\mathrm{a,b}), r_{g_A^u,G}(\mathrm{a,b})\right]$, $r_{\tilde{u},G}(\mathrm{a,b}) = \left[r_{u_A^l,G}(\mathrm{a,b}), r_{u_A^u,G}(\mathrm{a,b})\right]$ and
$r_{\tilde{f},G}(\mathrm{a,b}) = \left[r_{f_A^l,G}(\mathrm{a,b}), r_{f_A^u,G}(\mathrm{a,b})\right]$

Where

$r_{t_A^l,G}(\mathrm{a,b}) = max\left\{s_{t_A^l}(P): \mathrm{P} = (v_0, v_1, \dots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\right\}$,
$r_{t_A^u,G}(\mathrm{a,b}) = max\left\{s_{t_A^u}(P): \mathrm{P} = (v_0, v_1, \dots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\right\}$,
$r_{c_A^l,G}(\mathrm{a,b}) = min\left\{s_{c_A^l}(P): \mathrm{P} = (v_0, v_1, \dots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\right\}$,

$r_{c_A^u,G}(\mathrm{a,b}) = min\Big\{s_{c_A^u}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{g_A^l,G}(\mathrm{a,b}) = min\Big\{s_{g_A^l}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{g_A^u,G}(\mathrm{a,b}) = min\Big\{s_{g_A^u}(P)\text{ : P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{u_A^l,G}(\mathrm{a,b}) = min\Big\{s_{u_A^l}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{u_A^u,G}(\mathrm{a,b}) = min\Big\{s_{u_A^u}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{f_A^l,G}(\mathrm{a,b}) = min\Big\{s_{f_A^l}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$,

$r_{f_A^u,G}(\mathrm{a,b}) = min\Big\{s_{f_A^u}(P)\text{: P } = (v_0, v_1, \ldots, v_{nP}) \text{ in G } with\ v_0 = a\ and\ v_{nP} = b\Big\}$.

Definition 3.12. Let G = (A, B, V, E) be an IVPPNG and and let $\{v, \omega\}$ be an edge in G. Denote $G'_{\{v,\omega\}}$ as the partial-IVPPNG of G, in which $G'_{\{v,\omega\}}$ =(A', B', V', E') with $V = V'$and E'={$\{v, \omega\}$}. Then, $\{v, \omega\}$ is said to be an *interval valued pentapartitioned neutrosophic bridge* (IVPPNB) in G if at least one of the following conditions holds for some a,b ∈ V.

(i) $r_{\tilde{t},G'_{\{v,\omega\}}}(\mathrm{a,b}) < r_{\tilde{t},G}(\mathrm{a,b})$ (45)

(ii) $r_{\tilde{c},G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{\tilde{c},G}(\mathrm{a,b})$ (46)

(iii) $r_{\tilde{g},G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{\tilde{g},G}(\mathrm{a,b})$ (47)

(iv) $r_{\tilde{u},G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{\tilde{u},G}(\mathrm{a,b})$ (48)

(v) $r_{\tilde{f},G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{\tilde{f},G}(\mathrm{a,b})$ (49)

With $r_{t_A^l,G'_{\{v,\omega\}}}(\mathrm{a,b}) < r_{t_A^l,G}(\mathrm{a,b})$, $r_{t_A^u,G'_{\{v,\omega\}}}(\mathrm{a,b}) < r_{t_A^u,G}(\mathrm{a,b})$,
$r_{c_A^l,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{c_A^l,G}(\mathrm{a,b})$, $r_{c_A^u,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{c_A^u,G}(\mathrm{a,b})$,
$r_{g_A^l,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{g_A^l,G}(\mathrm{a,b})$, $r_{g_A^u,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{g_A^u,G}(\mathrm{a,b})$,
$r_{u_A^l,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{u_A^l,G}(\mathrm{a,b})$, $r_{u_A^u,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{u_A^u,G}(\mathrm{a,b})$ and
$r_{f_A^l,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{f_A^l,G}(\mathrm{a,b})$, $r_{f_A^u,G'_{\{v,\omega\}}}(\mathrm{a,b}) > r_{f_A^u,G}(\mathrm{a,b})$.

In particular, if all of the conditions (i)−(v) are true for some a,b ∈ V , then $\{v, \omega\}$ is said to be a strong interval valued pentapartitioned neutrosophic bridge (strong-IVPPNB) in G.

Definition 3.13. Let G =(A, B, V, E) be an IVPPNG and and let v be a vertex in G. Denote G'_v as the partial-IVPPNG of G, in which G'_v =(A', B', V', E') with $V' = V - \{\ v\}$ and E'= E-$\{\{a, v\}$: a$\in V - \{\ v\}\}$. Then, $v$is said to be an interval valued pentapartitioned neutrosophic cut vertex (IVPPNCV) in G if at least one of the following conditions holds for some a,b ∈ V

(i) $r_{\tilde{t},G'_v}(\mathrm{a,b}) < r_{\tilde{t},G}(\mathrm{a,b})$ (50)

(ii) $r_{\tilde{c},G'_v}(\mathrm{a,b}) > r_{\tilde{c},G}(\mathrm{a,b})$ (51)

(iii) $r_{\tilde{g},G'_v}(\mathrm{a,b}) > r_{\tilde{g},G}(\mathrm{a,b})$ (52)

(iv) $r_{\tilde{u},G_v'}(\mathrm{a,b}) > r_{\tilde{u},G}(\mathrm{a,b})$ (53)

(v) $r_{\tilde{f},G_v'}(\mathrm{a,b}) > r_{\tilde{f},G}(\mathrm{a,b})$ (54)

With $r_{t_A^l,G_v'}(\mathrm{a,b}) < r_{t_A^l,G}(\mathrm{a,b}),\ r_{t_A^u,G_v'}(\mathrm{a,b}) < r_{t_A^u,G}(\mathrm{a,b}),$
$r_{c_A^l,G_v'}(\mathrm{a,b}) > r_{c_A^l,G}(\mathrm{a,b}),\ r_{c_A^u,G_v'}(\mathrm{a,b}) > r_{c_A^u,G}(\mathrm{a,b}),$
$r_{g_A^l,G_v'}(\mathrm{a,b}) > r_{g_A^l,G}(\mathrm{a,b}),\ r_{g_A^u,G_v'}(\mathrm{a,b}) > r_{g_A^u,G}(\mathrm{a,b}),$
$r_{u_A^l,G_v'}(\mathrm{a,b}) > r_{u_A^l,G}(\mathrm{a,b}),\ r_{u_A^u,G_v'}(\mathrm{a,b}) > r_{u_A^u,G}(\mathrm{a,b})$ and
$r_{f_A^l,G_v'}(\mathrm{a,b}) > r_{f_A^l,G}(\mathrm{a,b}),\ r_{f_A^u,G_v'}(\mathrm{a,b}) > r_{f_A^u,G}(\mathrm{a,b}).$

In particular, if all of the conditions (i)–(v) are true for some a, b ∈ V, then v is said to be a strong interval valued pentapartitioned neutrosophic cut vertex (strong-IVPPNCV) in G.

Definition 3.15. Suppose that Ĝ= (P, Q) is an SVPN-graph. Then, the size of Ĝ= (P, Q), denoted by S(Ĝ) is defined by S(Ĝ)= (S_T(Ĝ), S_C(Ĝ), S_R(Ĝ), S_U(Ĝ), S_F(Ĝ)), where

$S_T(\hat{G})=\sum_{u\neq k} T_Q(u,k)$ denotes the T-size of Ĝ= (P, Q); (55)

$S_C(\hat{G})=\sum_{u\neq k} C_Q(u,k)$ denotes the C-size of Ĝ= (P, Q); (56)

$S_R(\hat{G})=\sum_{u\neq k} R_Q(u,k)$ denotes the R-size of Ĝ= (P, Q); (57)

$S_U(\hat{G})=\sum_{u\neq k} U_Q(u,k)$ denotes the U-size of Ĝ= (P, Q); (58)

$S_F(\hat{G})=\sum_{u\neq k} F_Q(u,k)$ denotes the F-size of Ĝ= (P, Q). (59)

4. Application in Decision Making Problem

Rapid development of the application of the fuzzy decision making in the real-life application is remarkable. There are many applications of the implementation of the fuzzy graph model in decision making is evident in the recent research articles. Multi attribute decision-making is one of the decision-making methods in which we analyze the attributes according to the criteria for the problems chosen and using an algorithm the attributes are evaluated and the best attributes will be selected. More models are proposed according to each further developments and extensions of the fuzzy theory, we have proposed the decision-making method according to the developed concept of interval valued Pentapartioned Neutrosohic graphs. The proposed algorithm using the interval valued Pentapartionied Neutrosophic graphs is as follows:

4.1. Algorithm:

Step 1: Input the attributes $A = \{A_1, A_2, \dots A_m\}$ and set of criteria $C = \{C_1, C_2, \dots C_n\}$.

Step 2: Construct the interval valued Pentapartitioned relation $K^i = \left(k_{lp}^{(i)}\right)_{mxm}$ where $i = 1,2, \dots n$ & $k_{lp}^i = \left(\left[T_{lp}^{(i)L},\ T_{lp}^{(i)U}\right], \left[C_{lp}^{(i)L},\ C_{lp}^{(i)U}\right], \left[U_{lp}^{(i)L},\ U_{lp}^{(i)U}\right], \left[G_{lp}^{(i)L},\ G_{lp}^{(i)U}\right], \left[F_{lp}^{(i)L},\ F_{lp}^{(i)U}\right]\right),\ l,p = 1,2, \dots n.$

Step 3: Compute the resultant adjacency matrix (K) for the attributes under the criteria using the intersection of all the interval valued Pentapartitioned relation (K^i) as given, $K = \bigcap_i K^i$

Step 4: Calculate the score value of resultant adjacency matrix K by using score function S_{ij}.

$$S_{lp} = \frac{\begin{matrix} T_{lp}^{L}+T_{lp}^{U}+\left(1-C_{lp}^{L}\right)+\left(1-C_{lp}^{U}\right)+\left(1-U_{lp}^{L}\right)+\left(1-U_{lp}^{U}\right)+ \\ \left(1-G_{lp}^{L}\right)+\left(1-G_{lp}^{U}\right)+\left(1-F_{lp}^{L}\right)\left(1-F_{lp}^{U}\right) \end{matrix}}{5} \tag{60}$$

Step 5: Calculate the choice values $A_h = \sum_j S_{hj}$ h, j=1,2,…m of each alternative.

Step 6: The final decision is the A_j with maximum choice value.

Step 7: If the j has more than one maximum value, then any one may be chosen.

4.2. An Illustrative Example:

In the fuzzy set and its extensions, the membership and the other membership degree function is sufficient but does not satisfy the needed vague categories. Thus, the introduction of the Pentapartitioned Neutrosophic set have paved the way for that advancement in the application area. It has five membership degree which mostly consider the vagueness of the real-life situations. The introduction of Interval valued Pentapartitioned Neutrosophic set is like a cream on top of the cake which adds more fuzziness in the conditions and criteria.

Now we consider the decision-making problems to choose the best international airline to take up the journey. The proposed decision-making method based on the interval valued Pentapartitioned Neutrosophic set and graph is used to solve this decision-making problem. The proposed method is more effective than the other proposed models due its membership degrees. Let the attributes be $A = \{A_1, A_2, \dots A_6\}$ where A_i's are the Airlines which we consider in our list. The selection of the best airline is based the criteria's $C = \{C_1, C_2, \dots C_5\}$. where the criteria's are

C_1 = Safe air travel for passengers during COVID-19 Airline safety rating.

C_2 = High standards of Airport.

C_3 = Onboard product with excellent standards of staff service delivery

C_4 = Specialist Intelligence and Save time & Resources

C_5 = Trusted Experience and Efficient workflows

Using the proposed method, we input the attributes and the criteria's. According to each criteria Interval valued Pentapartitioned Neutrosophic relation is developed (K_i) as directed graphs. Then the intersection of all the criteria's are calculated and the resultant matrix is given in a graph. Then the score values are calculated for each alternative and framed into a graph structure. The choice values are found for each attribute and arranged according to find the optimal alternative. The method of solving the selected problem is as follows.:

Step 1: The attributes $A = \{A_1, A_2, \dots A_6\}$ and criteria are $C = \{C_1, C_2, \dots C_6\}$.

Step 2: The interval valued Pentapartitioned relation K^i $(i = 1, 2, 3, 4, 5)$ is developed for each criteria as in the tables 2 to 6.

Table 2. Interval Valued Pentapartitioned Neutrosophic relation (K^1) for Criteria 1

K^1	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.1,0.5], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.1,0.4])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.5,0.8])	([0.2,0.4], [0.3,0.5], [0.2,0.8], [0.1,0.7], [0.3,0.6])	([0.4,0.8], [0.3,0.6], [0.3,0.7], [0.2,0.6], [0.1,0.6])	([0.2,0.7], [0.1,0.4], [0.3,0.7], [0.6,0.9], [0.4,0.6])
A_2	([0.1,0.5], [0.2,0.4], [0.2,0.6], [0.3,0.7], [0.4,0.8])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.2,0.6], [0.3,0.7], [0.4,0.8], [0.2,0.7], [0.1,0.6])	([0.1,0.6], [0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.8])	([0.2,0.6], [0.4,0.8], [0.1,0.6], [0.3,0.7], [0.5,0.9])	([0.4,0.8], [0.1,0.7], [0.5,0.8], [0.3,0.6], [0.2,0.6])
A_3	([0.3,0.6], [0.4,0.7], [0.1,0.5], [0.2,0.8], [0.1,0.6])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.5,0.9], [0.3,0.8], [0.2,0.6], [0.1,0.5], [0.3,0.7])	([0.3,0.8], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.1,0.5])	([0.1,0.5], [0.2,0.6], [0.3,0.7], [0.4,0.8], [0.5,0.8])
A_4	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.8])	([0.2,0.8], [0.3,0.9], [0.5,0.7], [0.3,0.6], [0.1,0.4])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])
A_5	([0.2,0.6], [0.1,0.5], [0.3,0.7], [0.4,0.7], [0.1,0.4])	([0.1,0.4], [0.3,0.7], [0.2,0.6], [0.4,0.9], [0.1,0.7])	([0.5,0.9], [0.4,0.7], [0.3,0.6], [0.1,0.7], [0.2,0.8])	([0.3,0.9], [0.5,0.8], [0.1,0.6], [0.2,0.7], [0.4,0.8])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.2,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])
A_6	([0.2,0.6], [0.3,0.5], [0.3,0.8], [0.4,0.9], [0.3,0.7])	([0.2,0.8], [0.3,0.6], [0.4,0.8], [0.5,0.7], [0.2,0.9])	([0.6,0.8], [0.5,0.7], [0.3,0.6], [0.2,0.7], [0.1,0.4])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.1,0.6], [0.3,0.8], [0.4,0.7], [0.1,0.8], [0.2,0.9])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])

Table 3. Interval Valued Pentapartitioned Neutrosophic relation (K^2) for Criteria 2

K^2	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])	([0.1,0.5], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.1,0.4])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.8])	([0.1,0.4], [0.3,0.7], [0.2,0.6], [0.4,0.9], [0.1,0.7])	([0.2,0.8], [0.3,0.6], [0.4,0.8], [0.5,0.7], [0.2,0.9])
A_2	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.8])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])	([0.2,0.6], [0.3,0.7], [0.4,0.8], [0.2,0.7], [0.1,0.5])	([0.2,0.7], [0.3,0.5], [0.4,0.8], [0.5,0.9], [0.4,0.6])	([0.2,0.6], [0.4,0.8], [0.1,0.6], [0.3,0.7], [0.5,0.9])	([0.4,0.8], [0.1,0.7], [0.5,0.8], [0.3,0.6], [0.2,0.6])
A_3	([0.2,0.8], [0.3,0.9], [0.5,0.7], [0.2,0.6],	([0.3,0.6], [0.4,0.7], [0.1,0.5], [0.2,0.8],	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9],	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8],	([0.4,0.7], [0.5,0.8], [0.3,0.6], [0.1,0.4],	([0.4,0.9], [0.5,0.8], [0.6,0.9], [0.3,0.7],

	[0.1,0.4])	[0.1,0.6])	[0.1,0.7])	[0.4,0.9])	[0.2,0.5])	[0.2,0.5])
A_4	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.6])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.5,0.9], [0.3,0.8], [0.2,0.6], [0.1,0.5], [0.3,0.7])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])	([0.3,0.8], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.2,0.5])	([0.2,0.6], [0.1,0.5], [0.3,0.7], [0.5,0.8], [0.6,0.9])
A_5	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])	([0.5,0.7], [0.4,0.6], [0.3,0.6], [0.2,0.5], [0.1,0.6])
A_6	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])	([0.4,0.7], [0.3,0.5], [0.2,0.6], [0.3,0.8], [0.5,0.9])	([0.5,0.8], [0.3,0.4], [0.4,0.7], [0.3,0.6], [0.2,0.6])	([0.3,0.5], [0.2,0.6], [0.5,0.8], [0.4,0.9], [0.6,0.9])	([0.4,0.6], [0.3,0.5], [0.2,0.8], [0.1,0.5], [0.6,0.9])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.1,0.7])

Table 4. Interval Valued Pentapartitioned Neutrosophic relation (K^3) for Criteria 3

K^3	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.5,0.9], [0.3,0.8], [0.2,0.6], [0.1,0.5], [0.3,0.7])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.4,0.6], [0.3,0.5], [0.2,0.8], [0.1,0.5], [0.6,0.9])	([0.5,0.7], [0.4,0.6], [0.3,0.6], [0.2,0.5], [0.1,0.6])
A_2	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8], [0.4,0.9])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.5])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.4,0.8], [0.1,0.7], [0.5,0.8], [0.3,0.6], [0.2,0.6])
A_3	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.4,0.7], [0.5,0.8], [0.3,0.6], [0.1,0.4], [0.2,0.5])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.5,0.8], [0.3,0.4], [0.4,0.7], [0.3,0.6], [0.2,0.5])	([0.1,0.4], [0.3,0.7], [0.2,0.6], [0.4,0.9], [0.1,0.7])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])
A_4	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])	([0.3,0.6], [0.4,0.7], [0.1,0.5], [0.2,0.8], [0.1,0.6])	([0.4,0.9], [0.5,0.8], [0.6,0.9], [0.5,0.7], [0.2,0.5])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8], [0.4,0.9])	([0.2,0.8], [0.3,0.6], [0.4,0.8], [0.5,0.7], [0.2,0.9])
A_5	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.8], [0.1,0.7])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])
A_6	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])	([0.1,0.5], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.1,0.4])	([0.3,0.6], [0.2,0.8], [0.5,0.7], [0.4,0.9], [0.3,0.8])

Table 5. Interval Valued Pentapartitioned Neutrosophic relation (K^4) for Criteria 4

K^4	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8], [0.4,0.9])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])
A_2	([0.5,0.9], [0.3,0.8], [0.2,0.6], [0.1,0.5], [0.3,0.7])	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])	([0.4,0.7], [0.5,0.8], [0.3,0.6], [0.1,0.4], [0.2,0.5])	([0.3,0.6], [0.4,0.7], [0.1,0.5], [0.2,0.8], [0.1,0.6])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])
A_3	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.1,0.7])	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])	([0.4,0.9], [0.5,0.8], [0.6,0.9], [0.5,0.7], [0.2,0.5])	([0.1,0.3], [0.2,0.8], [0.3,0.7], [0.4,0.7], [0.1,0.5])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])
A_4	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.5])	([0.5,0.8], [0.3,0.4], [0.4,0.7], [0.3,0.6], [0.2,0.5])	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.8], [0.1,0.6])	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])
A_5	([0.4,0.6], [0.3,0.5], [0.2,0.8], [0.1,0.4], [0.6,0.9])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.1,0.4], [0.3,0.7], [0.2,0.6], [0.4,0.9], [0.1,0.7])	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8], [0.4,0.6])	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])	([0.2,0.7], [0.1,0.5], [0.3,0.8], [0.5,0.9], [0.1,0.4])
A_6	([0.5,0.7], [0.4,0.6], [0.3,0.6], [0.2,0.5], [0.1,0.6])	([0.4,0.8], [0.1,0.7], [0.5,0.8], [0.3,0.6], [0.2,0.5])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])	([0.2,0.8], [0.3,0.6], [0.4,0.8], [0.5,0.7], [0.2,0.9])	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])	([0.3,0.5], [0.2,0.7], [0.5,0.9], [0.4,0.8], [0.3,0.8])

Table 6. Interval Valued Pentapartitioned Neutrosophic relation (K^5) for Criteria 5

K^5	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6], [0.3,0.5])	([0.3,0.7], [0.2,0.5], [0.1,0.4], [0.4,0.8], [0.3,0.6])	([0.1,0.5], [0.2,0.8], [0.3,0.6], [0.4,0.7], [0.2,0.6])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.4,0.6], [0.3,0.5], [0.2,0.8], [0.1,0.4], [0.6,0.9])	([0.5,0.7], [0.4,0.6], [0.3,0.6], [0.2,0.5], [0.1,0.6])
A_2	([0.4,0.8], [0.3,0.5], [0.4,0.6], [0.2,0.5], [0.3,0.9])	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6], [0.3,0.5])	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.2,0.4])	([0.1,0.6], [0.2,0.7], [0.3,0.8], [0.5,0.9], [0.2,0.5])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.1,0.5])	([0.4,0.8], [0.1,0.7], [0.5,0.8], [0.3,0.6], [0.2,0.5])
A_3	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9],	([0.4,0.7], [0.5,0.8], [0.3,0.6], [0.1,0.4],	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6],	([0.5,0.8], [0.3,0.4], [0.4,0.7], [0.3,0.6],	([0.1,0.4], [0.3,0.7], [0.2,0.6], [0.4,0.9],	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8],

	[0.2,0.8])	[0.2,0.5])	[0.3,0.5])	[0.2,0.5])	[0.1,0.5])	[0.1,0.4])
A4	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.8])	([0.3,0.6], [0.4,0.7], [0.1,0.5], [0.2,0.8], [0.1,0.6])	([0.4,0.9], [0.5,0.8], [0.6,0.9], [0.5,0.7], [0.2,0.5])	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6], [0.3,0.5])	([0.5,0.9], [0.3,0.8], [0.3,0.7], [0.2,0.8], [0.4,0.6])	([0.2,0.8], [0.3,0.6], [0.4,0.8], [0.5,0.7], [0.2,0.9])
A5	([0.6,0.8], [0.6,0.9], [0.5,0.7], [0.4,0.6], [0.1,0.3])	([0.3,0.7], [0.2,0.6], [0.4,0.5], [0.1,0.4], [0.2,0.8])	([0.1,0.3], [0.2,0.8], [0.3,0.7], [0.4,0.7], [0.6,0.9])	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.8], [0.1,0.6])	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6], [0.3,0.5])	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.3,0.5], [0.2,0.7])
A6	([0.7,0.9], [0.5,0.8], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.3,0.9], [0.1,0.4], [0.4,0.6], [0.6,0.9], [0.2,0.8])	([0.3,0.6], [0.4,0.7], [0.2,0.5], [0.2,0.8], [0.1,0.4])	([0.4,0.7], [0.2,0.6], [0.1,0.4], [0.3,0.8], [0.5,0.9])	([0.2,0.7], [0.1,0.5], [0.3,0.8], [0.5,0.9], [0.1,0.4])	([0.5,0.9], [0.3,0.8], [0.4,0.7], [0.2,0.6], [0.3,0.5])

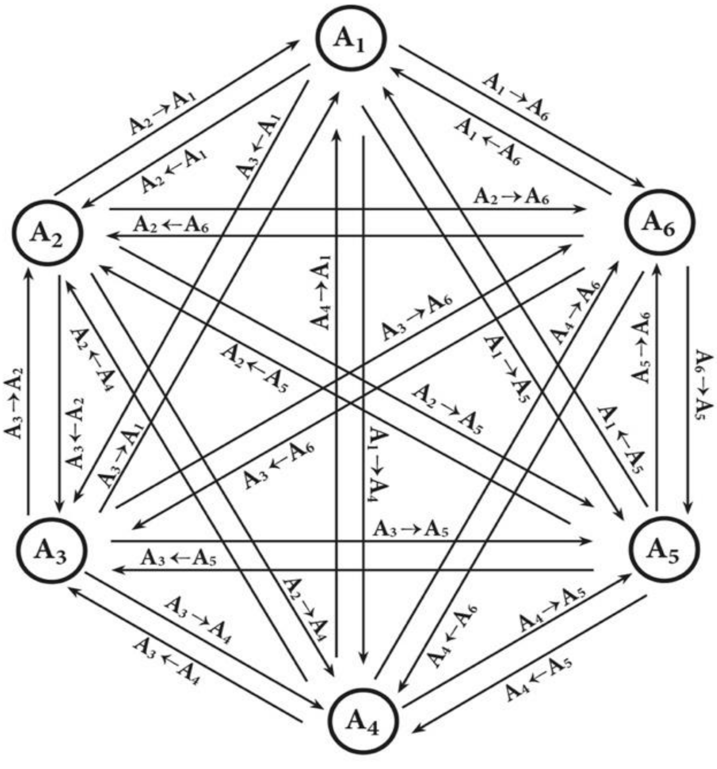


Figure 5: Interval Valued Pentapartitioned Neutrosophic directed graph structure for $C_i (i = 1, 2, 3, 4, 5)$

Step 3: From the interval valued Pentapartitioned relation K^i $(i = 1, 2, 3, 4, 5)$, computing the intersection and find the resultant matrix as in Table 7.

Table 7. The resultant matrix

K	A_1	A_2	A_3	A_4	A_5	A_6
A_1	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])	([0.1,0.5], [0.3,0.8], [0.3,0.8], [0.5,0.9], [0.4,0.9])	([0.1,0.5], [0.2,0.8], [0.4,0.6], [0.6,0.9], [0.5,0.8])	([0.1,0.4], [0.3,0.7], [0.4,0.8], [0.5,0.9], [0.5,0.8])	([0.1,0.4], [0.6,0.9], [0.5,0.8], [0.4,0.9], [0.6,0.9])	([0.2,0.7], [0.5,0.8], [0.4,0.8], [0.6,0.9], [0.4,0.9])
A_2	([0.1,0.5], [0.3,0.8], [0.4,0.8], [0.5,0.9], [0.4,0.9])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])	([0.2,0.6], [0.6,0.9], [0.5,0.8], [0.4,0.7], [0.2,0.6])	([0.1,0.6], [0.3,0.8], [0.4,0.8], [0.5,0.9], [0.5,0.8])	([0.2,0.6], [0.4,0.8], [0.4,0.6], [0.6,0.9], [0.5,0.9])	([0.3,0.8], [0.1,0.7], [0.5,0.8], [0.6,0.9], [0.2,0.8])
A_3	([0.1,0.5], [0.4,0.9], [0.5,0.7], [0.6,0.9], [0.2,0.8])	([0.1,0.5], [0.6,0.9], [0.5,0.7], [0.4,0.8], [0.2,0.7])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])	([0.4,0.8], [0.5,0.8], [0.6,0.9], [0.5,0.8], [0.4,0.9])	([0.1,0.3], [0.5,0.8], [0.5,0.9], [0.4,0.9], [0.2,0.7])	([0.1,0.5], [0.5,0.8], [0.6,0.9], [0.5,0.7], [0.5,0.8])
A_4	([0.2,0.5], [0.3,0.7], [0.4,0.9], [0.5,0.9], [0.5,0.8])	([0.1,0.5], [0.4,0.8], [0.3,0.8], [0.5,0.9], [0.2,0.8])	([0.2,0.8], [0.5,0.9], [0.6,0.9], [0.5,0.7], [0.3,0.7])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.6,0.9], [0.4,0.9])	([0.2,0.6], [0.4,0.7], [0.4,0.8], [0.5,0.8], [0.6,0.9])
A_5	([0.2,0.6], [0.6,0.9], [0.5,0.8], [0.6,0.9], [0.6,0.9])	([0.1,0.4], [0.3,0.7], [0.4,0.6], [0.6,0.9], [0.5,0.8])	([0.1,0.3], [0.6,0.9], [0.5,0.7], [0.4,0.9], [0.6,0.9])	([0.2,0.5], [0.5,0.8], [0.4,0.9], [0.5,0.8], [0.4,0.8])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])	([0.2,0.6], [0.5,0.8], [0.4,0.8], [0.5,0.9], [0.2,0.7])
A_6	([0.2,0.6], [0.5,0.8], [0.4,0.8], [0.6,0.9], [0.3,0.8])	([0.2,0.7], [0.3,0.7], [0.5,0.8], [0.6,0.9], [0.5,0.9])	([0.3,0.6], [0.5,0.7], [0.4,0.7], [0.3,0.8], [0.2,0.6])	([0.2,0.5], [0.3,0.8], [0.5,0.8], [0.5,0.9], [0.6,0.9])	([0.1,0.5], [0.5,0.8], [0.4,0.8], [0.5,0.9], [0.6,0.9])	([0.2,0.5], [0.3,0.8], [0.5,0.9], [0.5,0.9], [0.3,0.8])

Step 4: By using the score function S_{ij}, in the resultant matrix of Table 7, find the score matrix as in Table 8.

Table 8. The score matrix of K and the choice values of the Attributes A_j

K	A_1	A_2	A_3	A_4	A_5	A_6	Choice Value
A_1	0.74	0.74	0.76	0.72	0.58	0.72	4.24
A_2	0.72	0.74	0.82	0.74	0.74	0.9	4.66
A_3	0.72	0.76	0.74	0.68	0.7	0.66	4.26
A_4	0.74	0.78	0.78	0.86	0.68	0.74	4.58
A_5	0.6	0.74	0.58	0.72	0.74	0.76	4.14
A_6	0.74	0.78	0.94	0.68	0.64	0.74	4.52

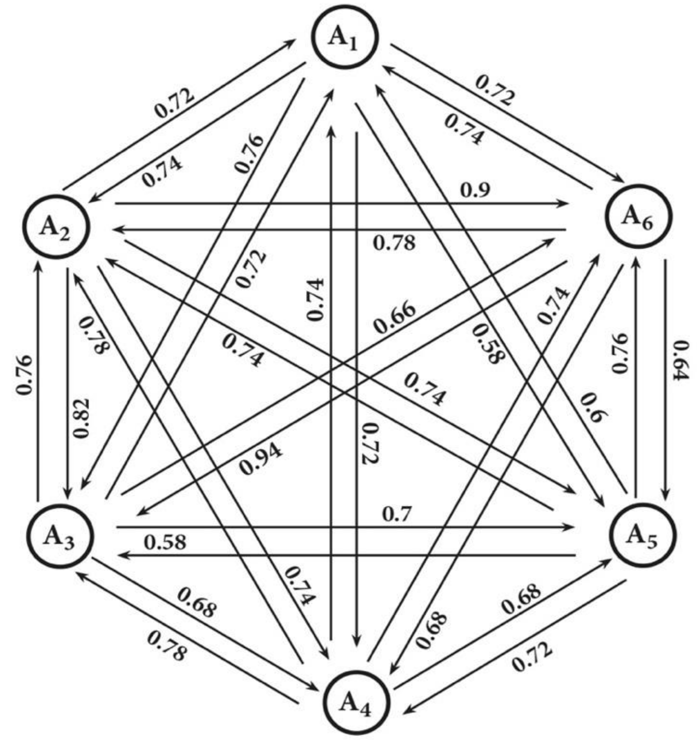


Figure 6. Interval Valued Pentapartitioned Neutrosophic directed graph with score values

Step 5: From the score matrix of Table 8, calculate the choice values for each attribute A_i $(i = 1\ to\ 6)$.

Step 6: Arrange the attributes according to their choice values in descending order, the final decision is A_2.

4.66 > 4.58 > 5.52 > 4.26 > 4.24 > 4.14

$$A_2 > A_4 > A_6 > A_3 > A_1 > A_5$$

By using the proposed decision-making method, the optimal decision is decided. By using the method, the alternatives are arranged in descending order and the second airline is chosen as the best airline with the condition which satisfies all the criteria.

5. Discussion

Interval valued pentapartitioned neutrosophic sets provide a powerful tool to represent the information with imprecise and indeterminate data and have fruitful applications. Pentapartitioned neutrosophic sets is an extension of the Neutrosophic sets with the membership function classified into five categories. The interval valued pentapartitioned neutrosophic sets which is introduced is an advancement of the pentapartitioned set like each membership representation comes in an interval. In this paper, the interval valued pentapartitioned neutrosophic sets have been implemented on the graph theoretical concepts and interval valued pentapartitioned neutrosophic graph have been developed. The significant operations of interval-valued pentapartitioned neutrosophic sets and its graphs are investigated. This helps the decision makers more sufficient for taking their input best suit to their domain of reference. The properties of interval valued pentapartitioned neutrosophic graph as cut vertex, bridge, degree are studied and examined with suitable examples. Hence, the proposed graphs and their basic properties have enough capabilities to address the related dependability on the indterminate information. A decision-making method have been developed using the interval valued pentapartitioned neutrosophic graph with a numerical illustration.

6. Conclusion

Interval valued pentapartitioned nutrosophic graphs are generalization of pentapartitioned nutrosophic graphs and provide a sufficient space for complex decision-making situations. In this research paper some properties of interval valued pentapartitioned neutrosophic graph as cut vertex, bridge, degree are studied and examined with suitable examples. Using the proposed Interval valued Pentapartitioned Nutrosophic graphs, a decision-making method has been developed and applied in a real-life situation with numerical illustrations. In future, concepts can be developed in the interval valued pentapartitioned neutrosophic soft graphs, interval valued quadripartitioned neutrosophic graphs, Strong interval valued pentapartitioned neutrosophic graphs, etc. Also, one can extend the developed concepts into isomorphic properties and regularity properties in the proposed graph structures. The Interval valued pentapartitioned neutrosophic graph can be extended to regular and irregular interval valued pentapartitioned neutrosophic graph, interval-valued pentapartitioned neutrosophic intersection graphs, interval-valued pentapartitioned neutrosophic hypergraphs, and so on. The interval-valued pentapartitioned neutrosophic graph can be used in modeling the network, telecommunication, image processing, computer networks, expert systems…etc.

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