Study of different degrees based on various operations on fuzzy soft graphs

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Abstract. In this paper, two operations, namely conjunction and disjunction on fuzzy soft graphs are defined. The degree and total degree of the vertices of the resultant fuzzy soft graph that are obtained from two given fuzzy soft graphs using these operations are determined. Further, we study properties of degree and total degree of a vertex in fuzzy soft graph based on these operations.
Keywords: degree of a vertex, total degree of a vertex, disjunction and conjunction of two fuzzy soft graphs.

1. Introduction

Graph theory has many interesting applications in various fields of computer science such as image segmentation, data mining, networking etc. Whenever there is uncertainty in the description of objects, fuzziness arises. A. Rosenfeld [1] developed the theory of fuzzy graphs.

In 1975 based on fuzzy sets which were initiated by Zadeh [2] in 1965. The concepts of operations on fuzzy graphs were presented by J. N. Mordeson and C. S. Peng [3]. Roy et al. [4] presented some applications of fuzzy soft sets to decision making problems. Sumit Mohinta and T.K. Samanta [5] introduced the notions of fuzzy soft graph, complete fuzzy soft graph and some of the operations such as union, intersection of two fuzzy soft graphs. M. Akram and Saira Nawaz [6] also introduced fuzzy soft graphs and studied few properties. Akram and Nawaz [7] in 2016, presented the concepts of fuzzy soft graphs and described

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applications of fuzzy soft graphs in social network and road network. Shashikala S and Anil P N [8] discussed connectivity in fuzzy soft graphs in comparison with their complements. Degree, total degree, regularity and total regularity of fuzzy soft graph and its properties are studied by A. Pouhassani and H. Doostie [9]. Anas Al-Masarwah and Majdoleen Abuqamar [10] introduced the concepts of uniform vertex fuzzy soft graphs, uniform edge fuzzy soft graphs, degree of a vertex and total degree of a vertex with some examples. SampathKumar [12] introduced the notion of graph structures. Maximal product of fuzzy graph structures, regular fuzzy graph structures, degree and total degree of a vertex in maximal product of fuzzy graph structures were introduced and some of its properties were presented [13]. Size and degree of fuzzy soft bi-partite graph are discussed and applied in employee selection for an organization by K. Malathy and S. Meenakshi [14].

In this paper, two operations namely, disjunction and conjunction of two fuzzy soft graphs are defined and some results related to degree and total degree of a vertex in fuzzy soft graph based on these operations are obtained.

2. Preliminaries

Definition 2.1 ([7]). *A fuzzy soft graph $\widetilde{G}$ over a graph $G^* : (V, E)$ is a triple $\widetilde{F}, \widetilde{K}, A)$ where*

a) A is a non-empty set of parameters

b) $(\widetilde{F}, A)$ is a fuzzy soft set over V

c) $(\widetilde{K}, A)$ is a fuzzy soft set over E

d) $((\widetilde{F}, (e_i)), (\widetilde{K}, (e_i)))$ is a fuzzy graph on G^* $\forall e_i \in A$

i.e.$\widetilde{K}(e_i)(xy) \leq min\{\widetilde{F}(e_i)(x), \widetilde{F}(e_i)(y)\}$ for all $e_i \in A$ and $x, y \in V$.

Definition 2.2 ([10]). *The underlying crisp graph of a fuzzy soft graph $\widetilde{G}$ is denoted by $G^* = (F^*, K^*)$ where $F^* = \{x \in V : \widetilde{F}(e_i)(x) > 0\}$, $K^* = \{(x, y) \in V \times V : \widetilde{K}(e_i)(x, y) > 0\}$ for some $e_i \in A$.*

Definition 2.3 ([10]). *Let $\widetilde{G}$ be a fuzzy soft graph on G^*. The degree of a vertex x is defined as $deg_{\widetilde{G}}(x) = \sum_{e_i \in A} \sum_{y \in V, y \neq x} \widetilde{K}(e_i)(xy)$.*

Definition 2.4 ([10]). *Let $\widetilde{G}$ be a fuzzy soft graph on G^*. The total degree of a vertex x is defined as $tdeg_{\widetilde{G}}(x) = \sum_{e_i \in A} \sum_{y \in V, y \neq x} \widetilde{K}(e_i)(xy) + \sum_{e_i \in A} \widetilde{F}(e_i)(x)$ i.e. $tdeg_{\widetilde{G}}(x) = deg_{\widetilde{G}}(x) + \sum_{e_i \in A} \widetilde{F}(e_i)(x)$.*

Definition 2.5 ([11]). *The degree $d_{G^*}(x)$ of a vertex v in G^* is the number of edges incident with x.*

In this paper, we assume that $G^* : (V, E)$ of any fuzzy soft graph $\widetilde{G}$ is finite and simple.

Notation. Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs. The relation $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$ for all $e_i \in A_1, e_j \in A_2$ means that $\widetilde{F}_1(e_i)(x) \geq \widetilde{K}_2(e_j)(e) \forall x \in V_1, e \in E_2$ where $\widetilde{F}_1$ is a fuzzy soft subset of V_1 and $\widetilde{K}_2$ is a fuzzy soft subset of E_2.

3. Disjunction of two fuzzy soft graphs $\widetilde{G_1} \vee \widetilde{G_2}$

Definition 3.1. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on G_1^* and G_2^* respectively.*

The disjunction $\widetilde{G_1} \vee \widetilde{G_2} : (\widetilde{F}_1 \vee \widetilde{F}_2, \widetilde{K}_1 \vee \widetilde{K}_2, A_1 \vee A_2)$ is defined as follows: $(\widetilde{F}_1 \vee \widetilde{F}_2) : A_1 \times A_2 \to FS(V_1 \times V_2)$ by $(\widetilde{F}_1 \vee \widetilde{F}_2)(e_i, e_j)(x_k y_l) = \widetilde{F}_1(e_i)(x_k) \vee \widetilde{F}_2(e_j)(y_l) \forall e_i \in A_1, e_j \in A_2, x_k y_l \in V_1 \times V_2$ and $(\widetilde{K}_1 \vee \widetilde{K}_2) : A_1 \times A_2 \to FS(E_1 \times E_2)$ by

$$(\widetilde{K}_1 \vee \widetilde{K}_2)(e_i, e_j)(x_k y_l)(x_m y_n) = \begin{cases} \widetilde{F}_1(e_i)(x_k) \vee \widetilde{K}_2(e_j)(y_l y_n), & \text{if } x_k = x_m, y_l y_n \in E_2 \\ \widetilde{F}_2(e_j)(y_l) \vee \widetilde{K}_1(e_i)(x_k x_m), & \text{if } y_l = y_n, x_k x_m \in E_1 \\ \widetilde{K}_1(e_i)(x_k x_m) \vee \widetilde{K}_2(e_j)(y_l y_n), & \text{if } x_k x_m \in E_1, y_l y_n \in E_2, \\ & x_k \neq x_m, y_l \neq y_n. \end{cases}$$

Definition 3.2. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively.*

Let $A = A_1 \times A_2$ then degree of a vertex $(x_k y_l) \in V_1 \times V_2$ in $\widetilde{G_1} \vee \widetilde{G_2}$ is

$$\begin{aligned} deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) &= \sum_{(e_i, e_j) \in A} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}(e_i, e_j)(x_k y_l)(x_m y_n) \\ &= \sum_{\substack{e_i \in A_1 \\ e_j \in A_2}} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{F}_1(e_i)(x_k) \vee \widetilde{K}_2(e_j)(y_l y_n) \\ &+ \sum_{\substack{e_i \in A_1 \\ e_j \in A_2}} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{F}_2(e_j)(y_l) \vee \widetilde{K}_1(e_i)(x_k x_m) \\ &+ \sum_{\substack{e_i \in A_1 \\ e_j \in A_2}} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_1(e_i)(x_k x_m) \vee \widetilde{K}_2(e_j)(y_l y_n). \end{aligned}$$

Definition 3.3. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively.*

Let $A = A_1 \times A_2$ *then total degree of a vertex* $(x_k y_l) \in V_1 \times V_2$ *in* $\widetilde{G_1} \vee \widetilde{G_2}$ *is*

$$tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) + \sum_{(e_i,e_j)\in A} (\widetilde{F}_1 \vee \widetilde{F}_2)(e_i, e_j)(x_k y_l)$$

$$= \sum_{\substack{e_i\in A_1 \\ e_j\in A_2}} \sum_{\substack{x_k=x_m \\ y_l y_n\in E_2}} \widetilde{F}_1(e_i)(x_k) \vee \widetilde{K}_2(e_j)(y_l y_n)$$

$$+ \sum_{\substack{e_i\in A_1 \\ e_j\in A_2}} \sum_{\substack{y_l=y_n \\ x_k x_m\in E_1}} \widetilde{F}_2(e_j)(y_l) \vee \widetilde{K}_1(e_i)(x_k x_m)$$

$$+ \sum_{\substack{e_i\in A_1 \\ e_j\in A_2}} \sum_{\substack{x_k x_m\in E_1 \\ y_l y_n\in E_2}} \widetilde{K}_1(e_i)(x_k x_m) \vee \widetilde{K}_2(e_j)(y_l y_n) + \sum_{(e_i,e_j)\in A} \widetilde{F}_1(e_i)(x_k) \vee \widetilde{F}_2(e_j)(y_l).$$

Example 3.1. Consider two fuzzy soft graphs $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $V_1 = x_1, x_2, x_3$, $E_1 = \{x_1x_2, x_1x_3, x_2x_3\}$, $V_2 = \{y_1, y_2\}$, $E_2 = \{y_1y_2\}$, $A_1 = \{e_i\}$ where $i = 1, 2$ and $A_2 = \{e_j\}$ where $j = 3, 4$. Let $(\widetilde{F}_1, A_1)$, $(\widetilde{F}_2, A_2)$, $(\widetilde{K}_1, A_1)$ and $(\widetilde{K}_2, A_2)$ be represented by the following Table 1.

$\widetilde{F}_1$	x_1	x_2	x_3	$\widetilde{F}_2$	y_1	y_2
e_1	0.4	0.5	0.6	e_3	0.3	0.3
e_2	0.3	0.4	0.5	e_4	0.2	0.2
$\widetilde{K}_1$	x_1x_2	x_1x_3	x_2x_3	$\widetilde{K}_2$	y_1y_2	
e_1	0.1	0.4	0.3	e_3	0.1	
e_2	0.3	0.3	0.2	e_4	0.3	

Table 1: Tabular representation of two fuzzy soft graphs

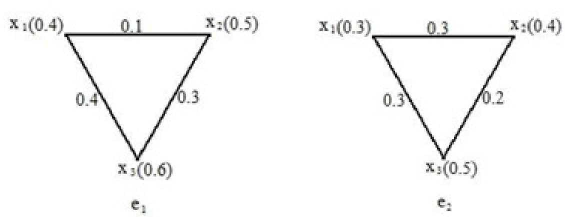

Figure 1: $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$

In a similar way, we get for (e_2, e_3) and (e_2, e_4).

$deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_1, y_1) = 6.7$

$tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_1, y_1) = 6.7 + 0.4 + 0.4 + 0.3 + 0.4 = 8.2$

Theorem 3.1. *Let* $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ *and* $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ *be two fuzzy soft graphs on* $G_1^* : (V_1, E_1)$ *and* $G_2^* : (V_2, E_2)$ *respectively. If* $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$,

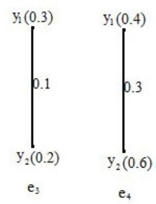

Figure 2: $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$

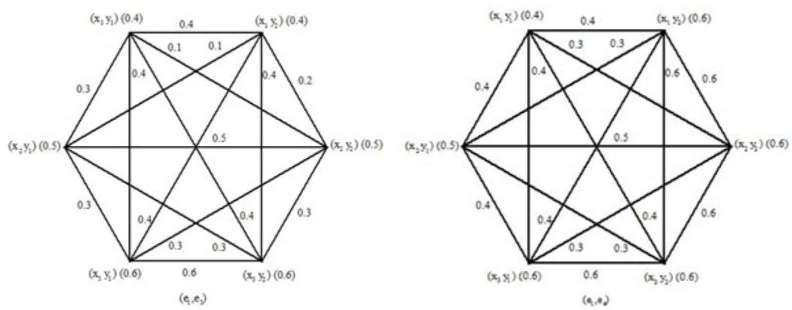

Figure 3: Disjunction $\widetilde{G}_1 \vee \widetilde{G}_2$

$\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ and $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, then

$$deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k) + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) + [d_{\widetilde{G}_2}(y_l)]|e_i| d_{G_1^*}(x_k).$$

Proof. Since $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ and $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, from Definition 3.2,

$$\begin{aligned} deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) &= \sum_{e_i \in A_1} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{F}_1(e_i)(x_k) \\ &+ \sum_{e_j \in A_2} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{F}_2(e_j)(y_l) + \sum_{e_j \in A_2} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_2(e_j)(y_l y_n) \\ &= |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k) + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) \\ &+ [d_{\widetilde{G}_2}(y_l)]|e_i| d_{G_1^*}(x_k). \end{aligned}$$

□

Corollary 3.1. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$,*

$\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ *and* $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, *then*

$$\begin{aligned} &deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) \\ &= |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k) + [td_{\widetilde{G}_2}(y_l)]|e_i| d_{G_1^*}(x_k). \end{aligned}$$

Proof. The proof follows from Theorem 3.1. □

Theorem 3.2. *Let* $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ *and* $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ *be two fuzzy soft graphs on* $G_1^* : (V_1, E_1)$ *and* $G_2^* : (V_2, E_2)$ *respectively. If* $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ *and* $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, *then*

$$\begin{aligned} &deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) \\ &= |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k) + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) + [d_{\widetilde{G}_1}(x_k)]|e_j| d_{G_2^*}(y_l). \end{aligned}$$

Proof. Since $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ and $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, from Definition 3.2,

$$\begin{aligned} deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) &= \sum_{e_i \in A_1} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{F}_1(e_i)(x_k) \\ &+ \sum_{e_j \in A_2} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{F}_2(e_j)(y_l) + \sum_{e_i \in A_1} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_1(e_i)(x_k x_m) \\ &= |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k) + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) \\ &+ [d_{\widetilde{G}_1}(x_k)]|e_j| d_{G_2^*}(y_l). \end{aligned}$$

□

Corollary 3.2. *Let* $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ *and* $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ *be two fuzzy soft graphs on* $G_1^* : (V_1, E_1)$ *and* $G_2^* : (V_2, E_2)$ *respectively. If* $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ *and* $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, *then*

$$deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) + [td_{\widetilde{G}_1}(x_k)]|e_j| d_{G_2^*}(y_l).$$

Proof. The proof follows from Theorem 3.2. □

Theorem 3.3. *Let* $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ *and* $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ *be two fuzzy soft graphs on* $G_1^* : (V_1, E_1)$ *and* $G_2^* : (V_2, E_2)$ *respectively. If* $\widetilde{F}_1(e_i) \leq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ *and* $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, *then* $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_i| d_{\widetilde{G}_2}(y_l)[1 + d_{G_1^*}(x_k)] + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)$.

Proof. Since $\widetilde{F}_1(e_i) \leq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ and $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, from Definition 3.2,

$$\begin{aligned}
&deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = \sum_{e_j \in A_2} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{K}_2(e_j)(y_l y_n) \\
&+ \sum_{e_j \in A_2} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{F}_2(e_j)(y_l) + \sum_{e_j \in A_2} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_2(e_j)(y_l y_n) \\
&= |e_i| d_{\widetilde{G}_2}(y_l) + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l) + [d_{\widetilde{G}_2}(y_l)] |e_i| d_{G_1^*}(x_k) \\
&= |e_i| d_{\widetilde{G}_2}(y_l)[1 + d_{G_1^*}(x_k)] + |e_i| d_{G_1^*}(x_k) \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l). \qquad \square
\end{aligned}$$

Corollary 3.3. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_1(e_i) \leq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$ and $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$, then $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_i|[d_{\widetilde{G}_2}(y_l) + td_{\widetilde{G}_2}(y_l) d_{G_1^*}(x_k)]$.*

Corollary 3.4. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_1(e_i) \leq \widetilde{K}_2(e_j)$, $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$ and $\widetilde{F}_2(e_j)$ is a constant function then $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_i|\{d_{\widetilde{G}_2}(y_l)[1 + d_{G_1^*}(x_k)] + c|e_j| d_{G_1^*}(x_k)\}$.*

Theorem 3.4. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_2(e_j) \leq \widetilde{K}_1(e_i)$, $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$ and $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, then $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_j| d_{\widetilde{G}_1}(x_k)[1 + d_{G_2^*}(y_l)] + |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k)$.*

Proof. Since $\widetilde{F}_2(e_j) \leq \widetilde{K}_1(e_i)$, $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$ and $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, from Definition 3.2,

$$\begin{aligned}
&deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = \sum_{e_i \in A_1} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{F}_1(e_i)(x_k) \\
&+ \sum_{e_i \in A_1} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{K}_1(e_i)(x_k x_m) + \sum_{e_i \in A_1} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_1(e_i)(x_k x_m) \\
&= |e_j| d_{\widetilde{G}_1}(x_k)[1 + d_{G_2^*}(y_l)] + |e_j| d_{G_2^*}(y_l) \sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k). \qquad \square
\end{aligned}$$

Corollary 3.5. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_2(e_j) \leq \widetilde{K}_1(e_i)$, $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$ and $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$, then $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_j|[d_{\widetilde{G}_1}(x_k) + td_{\widetilde{G}_1}(x_k) d_{G_2^*}(y_l)]$.*

Corollary 3.6. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{F}_2(e_j) \leq \widetilde{K}_1(e_i)$, $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$ and $\widetilde{F}_1(e_i)$ is a constant function then $deg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_j|\{d_{\widetilde{G}_1}(x_k)[1 + d_{G_2^*}(y_l)] + c|e_i|d_{G_2^*}(y_l)\}$.*

Theorem 3.5. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$, $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$ and $\widetilde{F}_2(e_j) \geq \widetilde{F}_1(e_i)$ then $tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = \big[\sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k)\big]|e_j|d_{G_2^*}(y_l) + [td_{\widetilde{G}_2}(y_l)]|e_i|d_{G_1^*}(x_k) + \big[\sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)\big]|e_i|$.*

Proof. From definition,

$$\begin{aligned}
tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) &= \sum_{e_i \in A_1} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{F}_1(e_i)(x_k) \\
&+ \sum_{e_j \in A_2} \sum_{\substack{y_l = y_n \\ x_k x_m \in E_1}} \widetilde{F}_2(e_j)(y_l) + \sum_{e_j \in A_2} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_2(e_j)(y_l y_n) \\
&+ \sum_{(e_i, e_j) \in A} \widetilde{F}_1(e_i)(x_k) \vee \widetilde{F}_2(e_j)(y_l) = \big[\sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k)\big]|e_j|d_{G_2^*}(y_l) \\
&+ \big[\sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)\big]|e_i|d_{G_1^*}(x_k) + [d_{\widetilde{G}_2}(y_l)]|e_i|d_{G_1^*}(x_k) \\
&+ \big[\sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)\big]|e_i| \\
&= tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = \big[\sum_{e_i \in A_1} \widetilde{F}_1(e_i)(x_k)\big]|e_j|d_{G_2^*}(y_l) \\
&+ [td_{\widetilde{G}_2}(y_l)]|e_i|d_{G_1^*}(x_k) + \big[\sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)\big]|e_i|. \qquad \square
\end{aligned}$$

Theorem 3.6. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $\widetilde{F}_1(e_i) \geq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$, $\widetilde{K}_2(e_j) \leq \widetilde{K}_1(e_i)$ and $\widetilde{F}_2(e_j) \geq \widetilde{F}_1(e_i)$ then $tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_j|d_{G_2^*}(y_l) + [td_{\widetilde{G}_1}(x_k)] + \big[\sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)\big]|e_i|[1 + d_{G_1^*}(x_k)]$.*

Proof. Proof is analogues to proof of Theorem 3.5. □

Theorem 3.7. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $\widetilde{F}_1(e_i) \leq \widetilde{K}_2(e_j)$, $\widetilde{F}_2(e_j) \geq \widetilde{K}_1(e_i)$, $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$ and $\widetilde{F}_1(e_i) \leq \widetilde{F}_2(e_j)$ then $tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = |e_i|td_{\widetilde{G}_2}(y_l)[1 + d_{G_1^*}(x_k)]$.*

Proof. From the definition,

$$tdeg_{\widetilde{G}_1 \vee \widetilde{G}_2}(x_k, y_l) = \sum_{e_j \in A_2} \sum_{\substack{x_k = x_m \\ y_l y_n \in E_2}} \widetilde{K}_2(e_j)(y_l y_n)$$

$$+\sum_{\substack{y_l=y_n\\x_kx_m\in E_1}}\widetilde{F}_2(e_j)(y_l)+\sum_{\substack{x_kx_m\in E_1\\y_ly_n\in E_2}}\widetilde{K}_2(e_j)(y_ly_n)$$
$$+\sum_{(e_i,e_j)\in A}\widetilde{F}_1(e_i)(x_k)\vee\widetilde{F}_2(e_j)(y_l)=|e_i|d_{\widetilde{G}_2}(y_l)$$
$$+\Big[\sum_{e_j\in A_2}\widetilde{F}_2(e_j)(y_l)\Big]|e_i|d_{G_1^*}(x_k)+[d_{\widetilde{G}_2}(y_l)]|e_i|d_{G_1^*}(x_k)$$
$$+\Big[\sum_{e_j\in A_2}\widetilde{F}_2(e_j)(y_l)\Big]|e_i|=|e_i|td_{\widetilde{G}_2}(y_l)[1+d_{G_1^*}(x_k)].\qquad\square$$

Theorem 3.8. *Let $\widetilde{G}_1:(\widetilde{F}_1,\widetilde{K}_1,A_1)$ and $\widetilde{G}_2:(\widetilde{F}_2,\widetilde{K}_2,A_2)$ be two fuzzy soft graphs on $G_1^*:(V_1,E_1)$ and $G_2^*:(V_2,E_2)$ respectively such that $\widetilde{F}_2(e_j)\le\widetilde{K}_1(e_i)$, $\widetilde{F}_1(e_i)\le\widetilde{K}_1(e_i)$, $\widetilde{K}_1(e_i)\le\widetilde{K}_2(e_j)$ and $\widetilde{F}_1(e_i)\le\widetilde{F}_2(e_j)$ then $tdeg_{\widetilde{G}_1\vee\widetilde{G}_2}(x_k,y_l)=|e_j|td_{\widetilde{G}_1}(x_k)[1+d_{G_2^*}(y_l)]$.*

Proof. Proof is similar to the proof of Theorem 3.7. $\square$

4. Conjunction of two fuzzy soft graphs $\widetilde{G_1}\wedge\widetilde{G_2}$

Definition 4.1. *Let $\widetilde{G}_1:(\widetilde{F}_1,\widetilde{K}_1,A_1)$ and $\widetilde{G}_2:(\widetilde{F}_2,\widetilde{K}_2,A_2)$ be two fuzzy soft graphs on G_1^* and G_2^* respectively. The conjunction $\widetilde{G_1}\wedge\widetilde{G_2}:(\widetilde{F}_1\wedge\widetilde{F}_2,\widetilde{K}_1\wedge\widetilde{K}_2,A_1\times A_2)$ is defined as follows: $(\widetilde{F}_1\wedge\widetilde{F}_2):A_1\times A_2\to FS(V_1\times V_2)$ by $(\widetilde{F}_1\wedge\widetilde{F}_2)(e_i,e_j)(x_ky_l)=\widetilde{F}_1(e_i)(x_k)\wedge\widetilde{F}_2(e_j)(y_l)\forall e_i\in A_1,e_j\in A_2,x_ky_l\in V_1\times V_2$ and $(\widetilde{K}_1\wedge\widetilde{K}_2):A_1\times A_2\to FS(E_1\times E_2)$ by $(\widetilde{K}_1\wedge\widetilde{K}_2)(e_i,e_j)(x_ky_l)(x_my_n)=\widetilde{K}_1(e_i)(x_kx_m)\wedge\widetilde{K}_2(e_j)(y_ly_n)\forall(x_ky_l)(x_my_n)\in E_1\times E_2$.*

Definition 4.2. *Let $\widetilde{G}_1:(\widetilde{F}_1,\widetilde{K}_1,A_1)$ and $\widetilde{G}_2:(\widetilde{F}_2,\widetilde{K}_2,A_2)$ be two fuzzy soft graphs on $G_1^*:(V_1,E_1)$ and $G_2^*:(V_2,E_2)$ respectively. Let $A=A_1\times A_2$ then degree of a vertex $(x_ky_l)\in V_1\times V_2$ in $\widetilde{G_1}\wedge\widetilde{G_2}$ is $deg_{\widetilde{G}_1\wedge\widetilde{G}_2}(x_k,y_l)=\sum_{(e_i,e_j)\in A}\sum_{\substack{x_kx_m\in E_1\\y_ly_n\in E_2}}\widetilde{K}(e_i,e_j)(x_ky_l)(x_my_n)=\sum_{\substack{e_i\in A_1\\e_j\in A_2}}\sum_{\substack{x_kx_m\in E_1\\y_ly_n\in E_2}}\widetilde{K}_1(e_i)(x_kx_m)\wedge\widetilde{K}_2(e_j)(y_ly_n)$.*

Definition 4.3. *Let $\widetilde{G}_1:(\widetilde{F}_1,\widetilde{K}_1,A_1)$ and $\widetilde{G}_2:(\widetilde{F}_2,\widetilde{K}_2,A_2)$ be two fuzzy soft graphs on $G_1^*:(V_1,E_1)$ and $G_2^*:(V_2,E_2)$ respectively. Let $A=A_1\times A_2$ then total degree of a vertex $(x_ky_l)\in V_1\times V_2$ in $\widetilde{G_1}\wedge\widetilde{G_2}$ is*

$$tdeg_{\widetilde{G}_1\wedge\widetilde{G}_2}(x_k,y_l)=deg_{\widetilde{G}_1\wedge\widetilde{G}_2}(x_k,y_l)+\sum_{(e_i,e_j)\in A}(\widetilde{F}_1\wedge\widetilde{F}_2)(e_i,e_j)(x_ky_l)$$
$$=\sum_{\substack{e_i\in A_1\\e_j\in A_2}}\sum_{\substack{x_kx_m\in E_1\\y_ly_n\in E_2}}\widetilde{K}_1(e_i)(x_kx_m)\wedge\widetilde{K}_2(e_j)(y_ly_n)+\sum_{(e_i,e_j)\in A}\widetilde{F}_1(e_i)(x_k)\wedge\widetilde{F}_2(e_j)(y_l).$$

Example 4.1. Consider two fuzzy soft graphs $\widetilde{G}_1:(\widetilde{F}_1,\widetilde{K}_1,A_1)$ and $\widetilde{G}_2:(\widetilde{F}_2,\widetilde{K}_2,A_2)$ on $G_1^*:(V_1,E_1)$ and $G_2^*:(V_2,E_2)$ respectively such that $V_1=x_1,x_2,$

$E_1 = \{x_1x_2\}$, $V_2 = \{y_1, y_2, y_3\}$, $E_2 = \{y_1y_2, y_1y_3, y_2y_3\}$, $A_1 = \{e_i\}$ where $i = 1, 2$ and $A_2 = \{e_j\}$ where $j = 3, 4$. Let $(\widetilde{F}_1, A_1)$, $(\widetilde{F}_2, A_2)$, $(\widetilde{K}_1, A_1)$ and $(\widetilde{K}_2, A_2)$ be represented by the following Table 2.

$\widetilde{F}_1$	x_1	x_2	$\widetilde{F}_2$	y_1	y_2	y_3
e_1	0.3	0.5	e_3	0.3	0.7	0.5
e_2	0.6	0.8	e_4	0.2	0.4	0.5
$\widetilde{K}_1$	x_1x_2		$\widetilde{K}_2$	y_1y_2	y_1y_3	y_2y_3
e_1	0.3		e_3	0.3	0.2	0.5
e_2	0.5		e_4	0.2	0.1	0.4

Table 2: Tabular representation of two fuzzy soft graphs

Figure 4: $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$

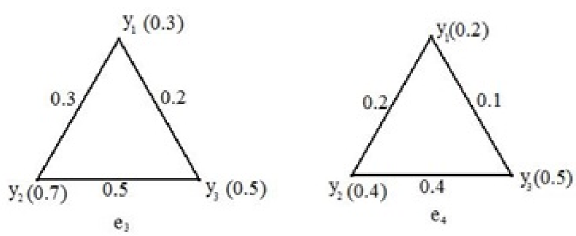

Figure 5: $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$

Similarly , we get for (e_2, e_3) and (e_2, e_4). $deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_1, y_1) = 0.5 + 0.3 + 0.3 + 0.5 = 1.6$. $tdeg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_1, y_1) = 1.6 + 0.3 + 0.2 + 0.2 + 0.3 = 2.6$.

Theorem 4.1. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{K}_1(e_i) \wedge \widetilde{K}_2(e_j)$ is a constant function then $deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = c d_{G_1^*}(x_k) d_{G_2^*}(y_l) |e_i||e_j|$.*

Proof. Let $\widetilde{K}_1(e_i) \wedge \widetilde{K}_2(e_j) = c$.

$deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = \sum_{(e_i,e_j)\in A} \sum_{\substack{x_kx_m \in E_1 \\ y_ly_n \in E_2}} [\widetilde{K}_1(e_i) \wedge \widetilde{K}_2(e_j)](x_ky_l)(x_my_n) = \sum_{(e_i,e_j)\in A} \sum_{\substack{x_kx_m \in E_1 \\ y_ly_n \in E_2}} c = c d_{G_1^*}(x_k) d_{G_2^*}(y_l) |e_i||e_j|$. □

Theorem 4.2. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$ then $deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = [d_{\widetilde{G}_1}(x_k)]|e_j| d_{G_2^*}(y_l)$.*

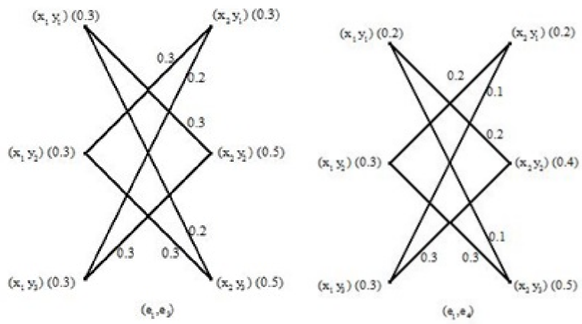

Figure 6: Conjunction $\widetilde{G_1} \wedge \widetilde{G_2}$

Proof. Since $\widetilde{K}_1(e_i) \leq \widetilde{K}_2(e_j)$,

$$deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = \sum_{(e_i,e_j)\in A} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_1(e_i)(x_k x_m)$$

$$= [d_{\widetilde{G}_1}(x_k)]|e_j| d_{G_2^*}(y_l).$$ □

Theorem 4.3. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively. If $\widetilde{K}_1(e_i) \geq \widetilde{K}_2(e_j)$ then $deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = [d_{\widetilde{G}_2}(y_l)]|e_i| d_{G_1^*}(x_k)$.*

Proof. The proof is similar to the proof of Theorem 4.2. □

Theorem 4.4. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $\widetilde{F}_1(e_i) \geq \widetilde{F}_2(e_j)$ and $\widetilde{K}_1(e_i) \geq \widetilde{K}_2(e_j)$ then $tdeg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = |e_i|[d_{G_1^*}(x_k) d_{\widetilde{G}_2}(y_l) + \sum_{e_j \in A_2} \widetilde{F}_2(e_j)(y_l)]$.*

Proof.

$$tdeg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = deg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) + \sum_{(e_i,e_j)\in A} (\widetilde{F}_1 \wedge \widetilde{F}_2)(e_i, e_j)(x_k, y_l)$$

$$= \sum_{\substack{e_i \in A_1 \\ e_j \in A_2}} \sum_{\substack{x_k x_m \in E_1 \\ y_l y_n \in E_2}} \widetilde{K}_1(e_i)(x_k x_m) \wedge \widetilde{K}_2(e_j)(y_l y_n)$$

$$+ \sum_{(e_i,e_j)\in A} \widetilde{F}_1(e_i)(x_k) \wedge \widetilde{F}_2(e_j)(y_l),$$

$$tdeg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = \sum_{\substack{e_i\in A_1 \\ e_j\in A_2}} \sum_{\substack{x_k x_m\in E_1 \\ y_l y_n\in E_2}} \widetilde{K}_2(e_j)(y_l y_n)$$

$$+ |e_i| \sum_{e_j\in A_2} \widetilde{F}_2(e_j)(y_l) = |e_i| \big[d_{G_1^*}(x_k) d_{\widetilde{G}_2}(y_l)$$

$$+ \sum_{e_j\in A_2} \widetilde{F}_2(e_j)(y_l) \big]. \qquad \square$$

Theorem 4.5. *Let $\widetilde{G}_1 : (\widetilde{F}_1, \widetilde{K}_1, A_1)$ and $\widetilde{G}_2 : (\widetilde{F}_2, \widetilde{K}_2, A_2)$ be two fuzzy soft graphs on $G_1^* : (V_1, E_1)$ and $G_2^* : (V_2, E_2)$ respectively such that $\widetilde{F}_2(e_j) \geq \widetilde{F}_1(e_i)$ and $\widetilde{K}_2(e_j) \geq \widetilde{K}_1(e_i)$ then $tdeg_{\widetilde{G}_1 \wedge \widetilde{G}_2}(x_k, y_l) = |e_j| \big[d_{G_2^*}(y_l) d_{\widetilde{G}_1}(x_k) + \sum_{e_i\in A_1} \widetilde{F}_1(e_i)(x_k) \big]$.*

Proof. The proof is similar to the proof of Theorem 4.4. $\square$

5. Conclusion

In this paper, disjunction and conjunction of two fuzzy soft graphs are defined and illustrated with examples. The degree and total degree of a vertex in the fuzzy soft graph formed by these operations is expressed in terms of the degree and total degree of vertices in the given fuzzy soft graphs in some particular cases. Some properties related to degree and total degree of a vertex in $\widetilde{G_1} \vee \widetilde{G_2}$ $\widetilde{G_1} \wedge \widetilde{G_2}$ are also analyzed.

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