APPLICATION OF INTUITIONISTIC FUZZY CRITICAL PATH MODEL FOR SELECTION OF BEST PERFORMER

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ABSTRACT:
The main objective of this article is to apply the intuitionistic fuzzy critical path model to identify the best performer in an institute/competition or a best performer during B.Tech course. The process of application of Intuitionistic Fuzzy Critical Path to identify the best performer at the completion of a course is explained in this article with an example using Trapezoidal intuitionistic fuzzy numbers. The criterion of selection is by defining the required characteristics, say the academic achievements, skills, leadership qualities, ethics/attitude, etc may include. The entire process of selection may be broken down into different small goals like achieving qualification, skill1, skill2, skill3, etc. Arrange the goals/skills/activities in an order to be acquired by the student and observing the time taken by the candidate to acquire each activity. Then the best performer can be estimated by using intuitionistic fuzzy critical path model.
Key words: Trapezoidal intuitionistic fuzzy number, Best performer, skill, intuitionistic fuzzy critical path.

1. Introduction

In 2012, P.K. De and Amita B., presented an algorithm to perform critical path analysis in a fuzzy environment. The ambiguities involved in the assessment activity time in project network can be improved for an effective project management decision-making.
In 2014, P. Jayagowri and G. Geetharamani[2,3], presented a novel approach to find the critical path in a directed acyclic graph, whose activity time is uncertain. The indistinguishable parameters in the network are represented by intuitionistic trapezoidal fuzzy numbers and triangular fuzzy numbers, instead of crisp numbers. A new procedure is proposed to find the optimal path with an illustrative example.
In 2017, T. Yogashanthi and K. Ganesan, proposed a new method to solve networking problems under an intuitionistic fuzzy environment using triangular Intuitionistic fuzzy numbers to represent activity duration in the project network. The intuitionistic fuzzy critical path for the project network using a new type of arithmetic operations and a ranking function on triangular intuitionistic fuzzy numbers with numerical example. In the same year, P. Jayagowri and T. Nallathambi, demonstrated the use of intuitionistic fuzzy critical path method to find airport's ground critical operations processes and improve, using the rating methodology of decision makers. Vague parameters in the project network were

represented by intuitionistic trapezoidal fuzzy numbers. Intuitionistic fuzzy critical length of the project network is found without defuzzification of the intuitionistic fuzzy activity times. In 2018, M. Balaganesan and K. Ganesan, proposed a new methodology to find the critical path. The imprecise parameters in the network diagram are represented by intuitionistic triangular fuzzy numbers, instead of crisp numbers with an illustrative example.

In 2021, Raut etal, calculated the shortest path in a directory graph in which vertices (nodes) and edges remain crisp and the edge weight is given by Trapezoidal fuzzy numbers using this concepts an algorithm is presented using fuzzy shortest path problem. The new algorithm works to find first the shortest path in the associated network and then second measures the degree between fuzzy shortest path length (FSPL) and each fuzzy path length, and the path having the highest similarity degree is the shortest path.

Yogashanthi etal., in the year 2021 expressed the method of intuitionistic fuzzy critical path improving the working process of the airfreight ground operation system. Instead of using the traditional method of finding critical path and total completion duration of intuitionistic fuzzy critical path analysis, here activity durations are represented as trapezoidal intuitionistic fuzzy numbers. Also, a new centroid based ranking grade of modal value, left fuzziness and right fuzziness index of membership and non-membership functions of trapezoidal intuitionistic fuzzy numbers has been applied.
Yogashanthi etal., in the year 2022, proposed the intuitionistic fuzzy version of the critical path method to solve networking problems with uncertain activity durations. Trapezoidal and the triangular intuitionistic fuzzy numbers are utilized to describe the uncertain activity or task durations of the project network. Here trapezoidal and triangular intuitionistic fuzzy numbers are converted into their corresponding parametric form and applying the proposed intuitionistic fuzzy arithmetic operations and a new method of ranking based on the parametric form of intuitionistic fuzzy numbers, the intuitionistic fuzzy critical path with vagueness reduced intuitionistic fuzzy completion duration of the project has been obtained.
Rijwan and Ravi Shankar, in the year 2023, said the Critical path method is an effective technique in project planning. An alternative is the intuitionistic fuzzy critical path method in finding the project characteristics.
Izabela etal., in the year 2024, applied selected MCDA methods within an Intuitionistic Fuzzy (IF) environment to personnel selection, analyzing multiple criteria with the participation of decision-makers. Through Monte Carlo simulation and fuzzy ranking, the study validates the efficacy of fuzzy ranking in practical multi-criteria decision-making scenarios, offering insights into decision robustness and stability. The proposed research provides a comprehensive approach to personnel selection, producing reliable and robust recommendations under changing input conditions. In the same year, Rijwan and Ravi Shankar, explored the application of CPM in conjunction with the Ranking Method and Graphical Method for scheduling projects characterized by uncertainties represented using Trapezoidal Intuitionistic Fuzzy Numbers (TIFNs). A case study is presented to demonstrate the proposed approach incorporation of TIFN, Ranking Method, and Graphical Method enhances the accuracy and flexibility of project scheduling in the face of uncertainty. The findings contribute to the growing body of knowledge in project management, offering a

robust methodology for handling imprecise information and ensuring the successful execution of projects in dynamic and uncertain environments.

In this article the authors, used the intuitionistic fuzzy critical path method (IFCPM) to assess the best performer in a course during assessment or to identify the best performer in a competition. It helps in the complex process of selecting the best one with required skill set. Each candidate undergoing the course or competition may have different membership values based on their level of interest and capability in achieving different skills. Similarly fuzzy non-membership function can be used to represent the skills which they lack or inefficiency in a particular skill. IFCPM can be utilized by the authorities to provide the insights into the skill set and qualification required for a competition or a course completion. The Ranking Method is employed to assess the priority of activities based on their influence on project completion time, considering the imprecision inherent in TrIFN. Additionally, the Graphical Method is utilized to visually represent the project network, facilitating a comprehensive understanding of interdependencies and critical paths. Critical path method can be used to identify the critical path of the skill set required for a best performer which involves mapping of essential skills or achievements needed to be the best in a course or a competition. Hence IFCPM can be designed to identify personalized performance.

2. Basic Definitions and formulas:

Definition 2.1(Zadeh, 1965): A fuzzy set A of a non empty set X is defined as $\{\langle x, \mu_A(x)\rangle : x \in X\}$ is the membership function of the fuzzy set A. Fuzzy set is a collection of objects with graded membership i.e. having degrees of membership.

Definition 2.2 (Atanassov, 1999): An intuitionistic fuzzy set A in X is a pair, A = (μ_A, ν_A), where μ_A, ν_A are functions from the set X to the closed interval [0, 1] of real numbers such that for each x∈X, 0≤ μ_Ax + ν_Ax ≤ 1, where μ_A is called the membership function of A and ν_A is called the non-membership function of A. Furthermore, we have $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$, called the hesitation function of x in A. $\pi_A(x)$ is the degree of indeterminacy, and $\pi_A(x) : X \to [0,1]$ and 0 ≤ π_A(x) ≤ 1for every x in A. $\pi_A(x)$ expresses the lack of knowledge of whether x belongs to IFS A or not.

Definition 2.3: Intuitionistic Fuzzy Number (IFN): An IFN A is
i) An IF subset of the real line.
ii) Normal i.e, there is an $x_0 \varepsilon R$ such that $\mu(x_0)$ =1 (so $\upsilon_A(x_0)$ =0).
iii) Convex for the Membership function $\mu_A(x)$, ie, $\mu_A(\lambda x_1 + (1-\lambda)x_2) \geq min(\mu_A(x_1), \mu_A(x_2))$ for every $x_1, x_2 \varepsilon R$, $\lambda \varepsilon [0,1]$.
iv)Concave for the non-membership function υ_A, i.e $\upsilon_A(\lambda x_1 + (1-\lambda)x_2) \leq max(\upsilon_A(x_1), \upsilon_A(x_2))$ for every $x_1, x_2 \varepsilon R$, $\lambda \varepsilon [0,1]$.

Definition 2.4: Triangular Fuzzy Number (TFN): A fuzzy Number A= (a_1,a_2,a_3) is said to be a triangular fuzzy number with following membership function μ_A(x) :

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \frac{a_3-x}{a_3-a_2}, & a_2 \le x \le a_3 \\ 0, & x > a_3 \end{cases},$$

Definition 2.5: Trapezoidal Intuitionistic Fuzzy Number (TrIFN): An Intuitionistic fuzzy Number(IFN), A= (a_1, a_2, a_3, a_4); (b_1,b_2, b_3, b_4) is considered as a trapezoidal intuitionistic fuzzy number with membership function $\mu_A(x)$ and non-membership function $\gamma_A(x)$ given by :

$$\mu_A(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \frac{a_4-x}{a_4-a_3}, & a_3 \le x \le a_4 \end{cases}, \quad \vartheta_A(x) = \begin{cases} \frac{b_2-x}{b_2-b_1}, & b_1 \le x \le b_2 \\ 1, & b_2 \le x \le b_3 \\ \frac{x-b_3}{b_3-b_4}, & b_3 \le x \le b_4 \end{cases}$$

Definition 2.6: Arithmetic operations on trapezoidal intuitionistic fuzzy numbers (TrIFNs): If A and B are Trapezoidal Intuitionistic fuzzy Numbers (TrIFNs), A= (a_1, a_2, a_3, a_4); (a'_1,a'_2, a'_3, a'_4), B= (b_1,b_2, b_3, b_4);(b'_1,b'_2, b'_3, b'_4) then :

i) Addition is defined as $A \oplus B$ = (a_1+ b_1, a_2+ b_2, a_3+ b_3, a_4+ b_4); (a'_1+ b'_1, a'_2+ b'_2, a'_3+ b'_3, a'_4+ b'_4),

ii) Subtraction is defined as $A \ominus B$ = (a_1- b_4, a_2- b_3, a_3- b_2, a_4- b_1); (a'_1- b'_4, a'_2- b'_3, a'_3- b'_2, a'_4- b'_1).

Definition 2.7: Ranking Functions for Trapezoidal Intuitionistic Fuzzy Numbers(TrIFNs): The ranking function for trapezoidal intuitionistic fuzzy number, $A = (a_1, a_2, a_3, a_4)$;);(a'_1, a'_2, a'_3, a'_4) utilizes both membership and non-membership functions and defined as:

$$R(A) = (\mu_{R(A)}, \gamma_{R(A)}) = \left(\left(\frac{a_1+2a_2+2a_3+a_4}{6} \right), \left(\frac{a'_2+a'_3}{2} \right) + \left(\frac{a'_4-a'_3-a'_2+a'_1}{6} \right) \right).$$

If A and B are Trapezoidal Intuitionistic fuzzy Numbers, A= (a_1, a_2, a_3, a_4); (a'_1,a'_2, a'_3, a'_4), B= (b_1,b_2, b_3, b_4);(b'_1,b'_2, b'_3, b'_4) be two intuitionistic fuzzy numbers then:

i) If R(A) > R(B) then A> B,

ii) If R(A) < R(B) then A< B,

iii) If R(A) = R(B) then $A = B$.

3. Intuitionistic Fuzzy Critical Path Method

The following are steps applied in the context of selection of best performer:

Step 1: Defining Criteria and Evaluations: Identify relevant criteria for evaluation (e.g., academic performance, extracurricular activities, leadership skills). Experts or evaluators can provide fuzzy judgments for each student against each criterion using TrIFNs. A TrIFN is represented by four values (a, b, c, d). For example, if a set of evaluators are assessing the academic performance of a candidate, they might use a TrIFN to represent their fuzzy judgment, such as (50, 60, 70, 80) where 50 and 80 are the minimum and maximum grades, and 60 and 70 represent the core range of the candidate's performance.

Step2: Aggregation and Ranking: Once evaluations are expressed as TrIFNs, aggregation techniques can be used to combine the evaluations for each performer. Different aggregation operators, like the Weighted Averaging Operator (WAO), can be employed to calculate a

composite TrIFN for each performer, considering the weights assigned to each criterion. A ranking method is then applied to the aggregated TrIFNs to determine the best performer. Various ranking methods, including score-based methods and distance-based methods, can be used.

Step 3: Fuzzy Critical Path Method (FCPM): (i)Critical Path: The FCPM identifies the sequence of activities that determine the overall achievement duration. (ii)Fuzzy Time Estimates: Instead of using single crisp values for activity durations, the FCPM uses fuzzy numbers (like intuitionistic trapezoidal numbers) to represent the uncertainty in time estimations. (iii)Best Performer**:** By considering the ranking of the aggregated intuitionistic fuzzy numbers representing activity durations, the FCPM can identify the most critical activities or skills(activities i.e skill that are most likely to affect the selection of a performer) and thus the best performer in terms of achieving time. In essence, by combining the aggregation and ranking of intuitionistic fuzzy trapezoidal numbers with the FCPM, you can accurately represent uncertainty in achievers time estimations. (iv)Identify the most critical activities: By ranking the aggregated intuitionistic fuzzy numbers, identify the activities that are most likely to affect achievers completion time. (v) Determine the best performer:The activity with the highest ranking in terms of achievement completion time can be considered the best performer

4. Computation

The intuitionistic fuzzy critical path is described using tree representation. Consider the intuitionistic fuzzy critical path shown in Fig.1 and the tree representation shown in Fig.2. It is clear that there are four paths namely, 1-4-5-6, 1-3-5-6, 1-4-6, 1-2-6.

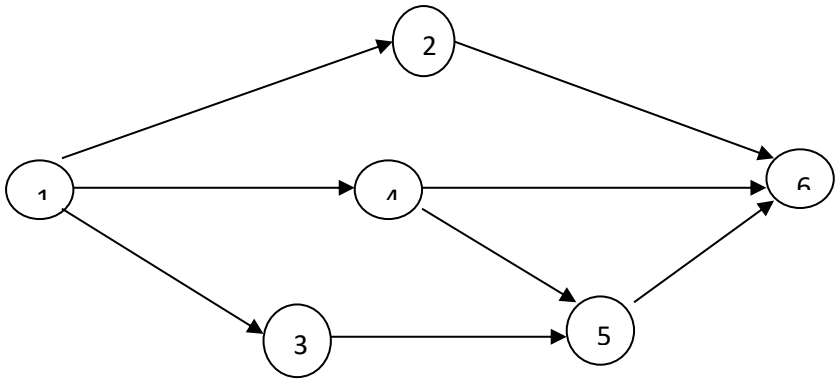

Fig.1 Intuitionistic Trapezoidal Fuzzy Project network

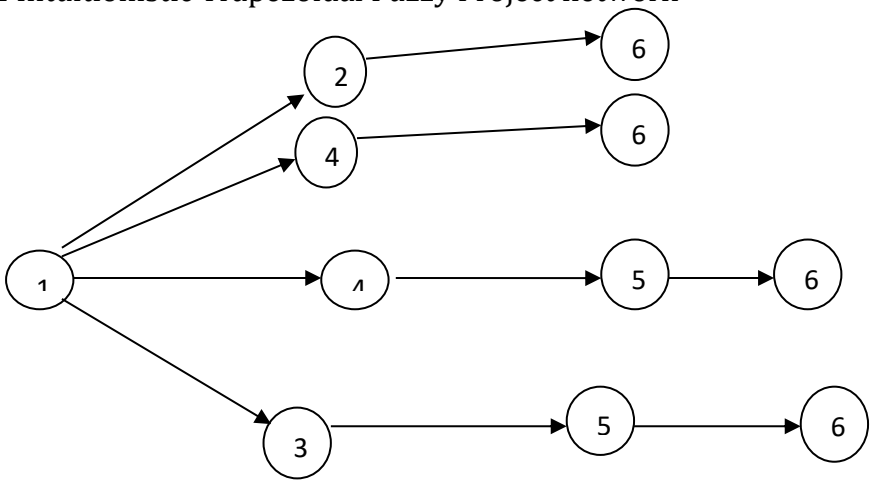

Fig.2 Tree representation Intuitionistic Trapezoidal Fuzzy Project network

4.1 Defuzzification of Total Float and Criticality Degree of Each Activity

Let A= (a_1, a_2, a_3, a_4);(a_1', a_2', a_3', a_4') be an intuitionistic trapezoidal fuzzy number representing total float of an activity. The defuzzification of **A** is given by $\left(\left(\frac{\mathbf{a_1+2a_2+2a_3+a_4}}{6}\right),\left(\frac{a_1'+2a_2'+2a_3'+a_4')}{6}\right)\right)$. Criticality degree of A is $\left(\left(\frac{-\mathbf{a_1}}{(\mathbf{a_2+a_3+a_4})}\right),\left(\frac{-a_1'}{(a_2'+a_3'+a_4')}\right)\right)$

4.2 Defuzzified Value and Critical Degree of Each Path in an Intuitionistic Fuzzy Critical Path

Let P be the set of all possible paths in the intuitionistic fuzzy project network. The defuzzified value of each path is calculated as the sum of all total floats of each activity present in the path. The intuitionistic fuzzy critical path is defined to be the path in P with smallest defuzzified value. The criticality degree of each path is defined as the minimum of all criticality degrees of activities present in the path belongs to P.

4.3 Procedure for Finding Intuitionistic Fuzzy Critical Path(IFCM)

Step1: G(V,E) where V is the set of vertices and E is the set of edges. Here G is an acyclic digraph and the length of each edge is represented as Trapezoidal Intuitionistic Fuzzy Number (TrIFN).
Step2: Find the intuitionistic fuzzy critical path obtained by comparing path lengths and obtain the intuitionistic path float of each path.
Step3: Calculate the total float of each activity for membership and non-membership functions.
Step4: Calculate the fuzzy earliest occurrence time of each node i.
Step5: Calculate the fuzzy earliest start time of each activity for membership and non-membership functions.
Step6: Calculate the Latest start time and latest finishing time for membership and non-membership functions.
Step7: Calculate the defuzzified value and critical degree of the total float for each activity for membership and non-membership functions.
Step8: Calculate the defuzzified value and criticality degree of each path with membership and non-membership functions. The path with criticality degree 1 is a critical path.

4.4 Illustration of the Proposed Method

To illustrate the proposed method for an Intuitionistic Trapezoidal Fuzzy Project Network with membership functions and non-membership functions, consider a fuzzy network in Fig.2 with activity times shown in Table 1.

S.No	Activity	Description	Activity time
1	1--2	Academic achievements	((12, 14, 16, 18),"(10, 15, 16, 18))
2	1--3	Sports Achievements –level 1	"((4, 10, 14, 18),(6, 10, 12, 14))"
3	1--4	"other achievements level1"	((8, 16, 20, 24), "(9, 13, 15, 17))"
4	2--6	"Assessment 1 "	"((5, 10, 15, 20), (12, 14, 15, 17))"

5	3--5	Sports Achievements –level 2””	“((12, 13, 15, 18), (16, 18, 20, 22))”
6	4--5	“other achievements level 2”	“((6, 10, 16, 24), (1, 2, 5, 7))”
7	4--6	“Assessment 2	“((13, 15, 17, 20), (11, 15, 18, 19))”
8	5--6	“Assessment 3”	“((5, 7, 9, 15), (6, 10, 12, 14))

Table1: Activity Times of IFCM

Step 1 : The distance from source node(1) to itself is (0,0,0,0);(0,0,0,0). The next level nodes accessible from node 1 are (2), (3), and (4). The distance i.e the achievement time from node (1) to node (2) is (12, 14,16,18); (10,15,16,18). Similarly all the achievement times are given in the Table 1. Using the ranking method in definition 2.7.
Step 2 : The maximum distance node from source node(1) to accessible nodes is node (4). The minimum distance node from source node (1) to accessible nodes is node (3). Accessible nodes from node (4) are node (5) and node (6). Accessible nodes from node (3) is node (5). The distance from node (4) to node (5) is (6,10,16,24);(1,2,5,7). The distance from node (4) to node (6) is (13,15,17,20);(11,15,18,19). The distance from node (3) to node (5) is (12,13,15,18);(16,18,20,22). Using the ranking method in definition 2.7, the maximum distance is from node(4) to node (5) with membership function value is (6,10,16,24) and the minimum distance is from node (3) to node (5) with non-membership function value is (12,13,15,18).
Step 3: The maximum distance node from node (4) to accessible nodes is node (5). The minimum distance node from node (3) to the accessible node is node (5). The accessible node from node (5) is node (6). The distance from node (5) to node (6) is (5,7,9,15);(6,10,12,14). Using the ranking method in definition 2.7, the maximum distance (achievement time) is from node (5) to (6) and the minimum distance is from node (5) to node (6). The membership function value is (5,7,9,15), and the non-membership function value is (6,10,12,14). Activity Activity time (Trapezoidal Intuitionistic fuzzy number) (1,2) (12,14,16,18) ; (10,15,16,18) (1,3) (4,10,14,18) ; (6, 10, 12,14) (1,4) (8,16,20,24); (9,13,15,17) (2,6) (5,10,15,20); (12,14,15,17) (3,5) (12,13,15,18); (16,18,20,22) (4,5) (6,10,16,24); (1,2,5,7) (4,6) (13,15,17,20); (11,15,18,19) (5,6) (5,7,9,15) ; (6,10,12,14).

Step 4 : The critical path is a path from the source node to the destination node as per the membership function. Here, the critical path is 1-4-5-6 using steps 1-3. The critical path is a path from the source node to the destination node as per the non-membership function. Here, the critical path is 1-3-5-6 using steps 1-3.

The critical path with Intuitionistic Trapezoidal fuzzy numbers are represented in table 1.
The Fuzzy paths :1-4-5-6, 1-3-5-6, 1-4-6,1-2-6 with their Fuzzy path lengths: (19,33,45,63); (16,25,32,38); (21,30,38,51), (28,38,44,50); (21,31,37,44); (20,28,33,36); (17,24,31,38); (22,29,31,35). Hence fuzzy critical path is 1-4-5-6. Fuzzy Project direction is (19,33,45,63); (16,25,32,38). Path float of 1-4-5-6: (-44, -12,12,44);(-22,-7,7,22).

Activity	Total Float Time								Earliest Start Time								Earliest Finish Time								Latest Start Time								Latest Finish Time							Defuuzified total float value		Critical Degree	
	a1	a2	a3	a4	a1'	a2'	a3'	a4'	a1	a2	a3	a4	a1'	a2'	a3'	a4'	a1	a2	a3	a4	a1'	a2'	a3'	a4'	a1	a2	a3	a4	a1'	a2'	a3'	a4'	a1	a2	a3	a4	a1'	a2'	a3'	membership	non-membership	membership	non-membership
1--2	-19	2	21	46	-19	-6	3	16	0	0	0	0	0	0	0	0	12	14	16	18	10	15	16	18	-19	2	21	46	-19	6	3	16	-1	18	35	58	-37	-22	-12	12.167	-1.5	0.2754	1.4615
1--3	-32	-5	15	42	-34	-19	-6	10	0	0	0	0	0	0	0	0	4	10	14	18	6	10	12	14	-32	5	15	42	-34	-19	6	10	-14	9	25	46	-48	-31	-16	5	-12.3333	0.6154	-2.267
1--4	-44	-12	12	44	-22	-7	7	22	0	0	0	0	0	0	0	0	8	16	20	24	9	13	15	17	-44	-12	12	44	-22	-7	7	22	-20	8	28	52	-39	-22	6	0	0	1	1
2--6	-19	2	21	46	-19	-6	3	16	12	14	16	18	10	15	16	18	17	24	31	38	16	25	32	38	-1	18	35	58	-37	-22	12	6	19	33	45	63	-54	-37	26	12.167	-1.5	0.2754	1.4615
3--5	-32	-5	15	42	-34	-19	-6	10	4	10	14	18	6	10	12	14	16	23	29	36	10	15	20	24	-14	9	25	46	-48	-29	16	4	4	24	38	58	-70	-49	-34	5	-12.3333	0.6154	-2.267
4--5	-44	-12	12	44	-22	-7	7	22	8	16	20	24	9	13	15	17	14	26	36	48	10	15	20	24	-20	8	28	52	-39	-22	14	13	4	24	38	58	-46	-27	-16	0	0	1	1
4--6	-25	-4	14	42	-20	-8	4	18	8	16	20	24	10	15	20	24	21	31	37	44	16	25	32	38	-1	16	30	50	-37	-23	-9	9	19	33	45	63	-56	-41	-24	6.1667	-1.66667	0.4808	1.4286
5--6	-44	-12	12	44	-22	-7	7	22	14	26	36	48	16	25	32	38	19	33	45	63	16	25	32	38	4	24	38	58	-46	-27	-8	12	19	33	45	63	-60	-39	-18	0	0	1	1

Table2:Intuiionistic Trapezoidal Fuzzy Times of a Fuzzy critical path

Fuzzy Paths	Fuzzy path length								Path Float								Defuzzified value	critical degree
1--2--6	17	24	31	38	22	29	31	35	-21	-7	7	21	-13	-2	2	13	-1.5	1.46
1--3--5--6	21	30	38	51	28	38	44	50	-30	-8	8	30	-22	-6	6	22	-12.33	-2.266666667
1--4--5--6	19	33	45	63	16	25	32	38	-44	-12	12	44	-22	-7	7	22	0	1
									0	0	0	0	0	0	0	0		
1--4--6	21	31	37	44	20	28	33	36	-23	-6	6	23	-16	-5	5	16	-1.66	1

Table3: Defuzzified Value and Criticality Degree of each Path in Intuitionistic Fuzzy Critical path

5. Conclusion

Fuzzy critical path method is used considering the different parameters for choosing the best performer instead of the conventional method which includes ambiguity. The Intuitionistic Fuzzy Critical Path concept is used to identify the best performer at the completion of a course or a selection process by defining the required skills as goals to be attained in a specific range of time. As per the importance of a skill (activity) to be achieved with a specific range of time is represented as trapezoidal intuitionistic fuzzy number. Then the set of skills to be achieved/ required in an order are arranged as goals or activity. The critical path i.e the sequence of tasks that are completed in shortest time presenting the performance of the candidate acquiring maximum skills. This might involve tasks that are time-sensitive or crucial for academic success.

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