# Comparative Study to Find the Critical Path Using Triangular Fuzzy Number

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**ABSTRACT**
The “Shortest path” problem which is a well-known and elemental problem in “Operational Research” associated to finding a path between two vertices (i.e. nodes) of a graph such that the sum of the weights ( like Cost, time and Distance) of its connecting edges is minimize. This problem is associated with many real-world applications.The Critical path problem is a classic and significant network optimization problem that appears in many applications, particularly in project planning and control the complex project, to implement the CPM we want clear determination of time duration. The out come of a conventional critical path approach computation does not accurately reflect the real-world situation. In this paper we developed a fuzzy critical path approach when the collected data’s are expressed in terms of triangular fuzzy numbers. In this article we presents a network based on critical path environment. The primary contribution of the work is to find the critical path by ranking method. A numerical example is shown to highlight the procedure of the proposed method at the end of this paper.

**Keywords:** Fuzzy logic, Critical path, Centroid ranking method, Robust ranking technique and Haar ranking method.

## 1. INTRODUTION

Project Association's capacity to organise operations and monitor progress within strict money, performance and time criteria is becometoday's more competitive Industry market.

The purpose of study of this research is to find the critical path by using triangular fuzzy number. There are many methodsareused in the past years. The approach that we are going to solve the first method called Centroid ranking method was proposed by Yager (15) in 1981, second method is Robust ranking technique was proposed by DaruneeHunwisai and Room Kumar and the last one is called Haar ranking method was proposed by A Haar (9) in 1909. More over in this paper, the diagram of critical path obtained by using triangular fuzzy number in various method are shown. .

Arun Pratap Singh [13] presented Allocation of subjects in an educational institution by Robust ranking method. Kokila et al [14] used Robust ranking method for solving Fuzzy Octagonal number. In 1965, Zadeh introduced Fuzzy set. It plays a crucial role in solving the real-world problems. Thereafter, Bellman and Zadeh have applied the decision-making concept in fuzzy nature. In 1991, Fuzzy set theory and its applications was discussed by Zimmermann [16]. Rangarajan et al [20] computed Hungarian assignment problems with fuzzy numbers by applying robust ranking techniques to change the fuzzy assignment problem to crisp. MonalishaPattnaik [21] applied Robust ranking for two phase fuzzy Optimization.

Vidhya et al. [24] studied the comparison between fuzzy Floyd Warshall and fuzzy rectangular algorithm for [26] the proposed the q-rung orthopair fuzzy sets(q-ROFS) which is a new concept in describing the complex uncertainty information. Unfortunately, IFS, PyFS and q-ROFS theories have their own limitations related to membership and non-membership grades, to eradicate this Riaz et.al [27] introduced the Linear Diophantine fuzzy set LDFS.“Fuzzy Rectangular algorithm” is used to locate the shortest path with a minimal amount of computational effort [29]. This problem is associated with many real-world applications. Chuang et.al and Kung et.al explained The Fuzzy Shortest Path Length and the Corresponding Shortest Path in a Network [30]. Deng et.al worked on Dijkstra Algorithm For the Fuzzy Shortest Path Problem under uncertain environment [31]. Liu worked on Network flow problem with fuzzy arc length [32]. Chou proposed on Canonical representation of triangular fuzzy number under multiplication operator [33]. Dharmarajand Appasamy [39] applied a modified Gauss eliminationtechnique for separable fuzzy nonlinear programming Problems. Prakash and Appasamy [37]worked on solving the Optimal Solution for Fully SphericalFuzzy Linear Programming Problems. Researchers foundways to solve problems with triangular fuzzy numbers using amathematical approach in the past. Saraswathi (38) triedfuzzy-trapezoidal dematel approach method for solvingdecision making problems under uncertainty.A heuristic based approach using A*algorithm with an interval valued Pythagorean fuzzy number for single source SPP was proposed by Vidhya et al. [40]. The remaining section of this paper is organized as follows. Section two introduces the concept of fuzzy logic, fuzzy set, Triangular fuzzy numbers and arithmetic operations and related results. Sections three presents the fuzzy critical path method and perform the calculations based forward pass computation and backward pass computation and ranking functions. Section four investigates a numerical example is provided to show the efficiency of the critical path activity and activity duration using the triangular fuzzy number. Section five, some conclusions are pointed out in the end of this paper based on our discussion.

## 2. Preliminaries

### 2.1 Fuzzy Logic

It has quickly become most used approaches for building complicated control systems today. The reason it is suitable for such uses because it closely recycles human decisions and capacity to develop exact solutions from limited ambiguous data.

Fuzzy logic is a method of describing and processing ambiguous data. In the more traditional propositional logic, such as ‘it will rain tomorrow’, must be either true or false. However, much of the fact’s humans use about the world has some ambiguity.

Fuzzy- “Not clear, distinct, or precise; blurred.”

### 2.2 Fuzzy Set

If X is an universal set and $x \in X$, then a fuzzy set $\widetilde{A}$ defined as a collection of ordered pairs,

$\widetilde{A} = \{(x, \mu_{\widetilde{A}}(x)), x \in X\}$

Where $\mu_{\widetilde{A}}(x)$ is called the membership function that maps X to the membership space M.

### 2.3 Triangular Fuzzy number

A triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is defined by its membership function

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

Where $a_2$ denotes the modal value of fuzzy number $a_1, a_3$ are left and right-hand deviation from the modal or middle value.

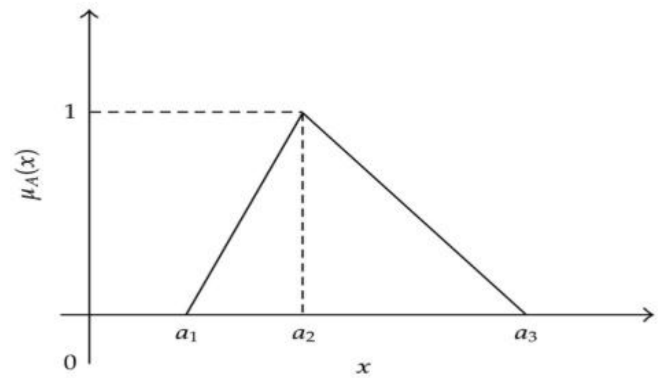


**Figure 1.** Triangular Fuzzy number

**2.4 Fuzzy Number**

Fuzzy set defined on the set R of real numbers is called fuzzy number whose membership function is of the form $\tilde{A}$: R→ [0,1] under certain condition

1. $\tilde{A}$ is normal
2. $\tilde{A}$ is convex
3. $\tilde{A}$ is piecewise continuous

**2.5 Arithmetic Operation of Triangular Fuzzy Number**

For arbitrary triangular fuzzy numbers $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ and $* = \{+, -, \times, \div\}$,

It is defined by $\tilde{A} * \tilde{B} = \{a_i * b_j / a_i \in \tilde{A}, b_j \in \tilde{B}\}$.

we define

**(i)Addition** (+): $A + B = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$

**(ii)Subtraction** (-): $A - B = (a_1 - b_1, a_2 - b_2, a_3 - b_3)$

**(iii)Multiplication** ( $\otimes$ ) :

$$k \otimes A = (ka_1, ka_2, ka_3), \;\; k \in R, \; k \geq 0$$

$$A \otimes b = (a_1 b, a_2 b, a_3 b), \; a_1 \geq 0, \; a_2 \geq 0, a_3 \geq 0$$

**(iv) Division** ( $\varnothing$ )

$$(A)^{-1} = (a_1, b_1, c_1)^{-1} \cong \left( \frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1} \right), \; a_1 > 0 \text{ , } b_1 > 0, \; c_1 > 0$$

$$A \varnothing B \cong \left( \frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_2} \right), \; a_1 \geq 0, \; a_2 > 0$$

**3. Critical Path**

A critical path for a project is the series of activities that determines the earliest time by which the project can be completed.

The critical path means longest path from start to end.

The sequence of critical activities in a network is called critical path.

The critical path is the longest path in the network form starting event to ending event and defines the minimum time required to complete the project

**3.1 Critical Activities**

Activities with zero total float are considered critical. In other words, an activity is regarded critical if delaying its start will cause the project's completion deadline to fall further.

**3.2 Critical Event**

Event i is call critical if $E_i = L_i$. Event and node both are same meaning. critical events have zero slack times.

**Network study of critical paths Calculate the basic schedule**

(i , j)=Activity with tail event i and head event j is the notation used.

$E_i$= Event i's earliest occurrence.

$L_j$ = Event j's most recent allowed occurrence time

$D_{ij}$ denotes the activity's expected completion time ( i, j)

$(Es)_{ij}$= The time when an action first begins ( i, j)

$(Ef)_{ij}$ =Activity's earliest completion time (i, j)

$(Ls)_{ij}$= activity's most recent start time (i, j)

$(Lf)_{ij}$= Activity's most recent finish time ( i, j)

**3.3 Forward Pass Computation**

**Step 1**

The calculation starts at the first event and progresses to the end event.

For simplicity, It assumes that the earliest occurrence time for the original event is zero.

**Step 2**
* The earliest activity start time (i ,j) is the earliest event start time of the tail end event,
i.e. $(Es)_{ij} = E_i$
*The earliest activity end time (i , j) equals the earliest starting time Plus the activity time,
i.e. $(Ef)_{ij} = (Es)_{ij} + D_{ij}$ or $(Ef)_{ij} = E_i + D_{ij}$
*The earliest event time for event j is the maximum of all activities ending into the event's earliest finish time, i.e. $E_i$= max $[(Ef)_{ij}]$ for all immediate predecessors of(i,j)or $E_j$= max $[E_i+D_{ij}]$

### 3.4 Backward Pass Computation

**Step 1**
Assume E=L for the terminating event. Remember that forward pass computations were used to compute all E's.
**Step 2**
The most recent time for activity (i, j) is the same as the most recent event time for event j. (i.e.) $L_j = (Lf)_{ij}$
**Step 3**
$(Ls)_{ij} = (Lf)_{ij} - D_{ij}$ or $(Ls)ij = L_j - D_{ij}$
**Step 4**
For all immediate successors of (i , j)= min (Ls)ij, the new event time for event'i' is the minimum of the new start time of all activities arising that event, i.e. $L_I$=min $(Ls)_{ij}$=min $[(Lf)_{ij}-D_{ij}]$

### 3.5 Ranking Function

**In this study, we consider the following Ranking functions:**
**Type 1**
An efficient approach for comparing the fuzzy numbers is by the use of a ranking function (Liou and Wang ,1992) R: F(R) R, where F(R) is a set of fuzzy numbers defined on set of real numbers, which maps each fuzzy number into the real line where a natural order exists.

Let (a,b,c) be a triangular fuzzy number then R( a, b, c) = $\frac{a+2b+c}{4}$ Also , let

(m, α, β) be a triangular fuzzy number then R (m, α, β) = m+ $\frac{\beta-\alpha}{4}$

**Type 2: Centroid Ranking method**

The centroid of a triangle fuzzy number a = (a, b , c; w) as $G_a = \left(\frac{a+b+c}{3}, \frac{w}{3}\right)$.The ranking function of the generalized fuzzy number a=(a, b, c ; w) which maps the set of all fuzzy numbers to a set of real numbers is defined a $R(a) = \left(\frac{a+b+c}{3}\right)\left(\frac{w}{3}\right)$.

**Type 3: Robust ranking technique**
Robust ranking technique which satisfies compensation, linearity, additive properties and provides result which consist of human intuition. if a is fuzzy number, then the Robust ranking is defined by
$$R(a) = 0.5\int_0^1 \left(a_\alpha^L, a_\alpha^U\right) d\alpha$$
Where $\left(a_\alpha^I, a_\alpha^U\right)$ is the α-level cut of the fuzzy number a and
$\left(a_\alpha^I, a_\alpha^U\right)$ ={((b-a) +a), (d-(d-c))}

### 4. Numerical Example

The triangular fuzzy project network issue is described in this part to show the computing method of fuzzy critical path analysis as stated previously.

**Example**
The Following table is the critical path activity and activity duration using the triangular fuzzy number.

| Activity | Activity duration |
|---|---|
| 1-2 | (25,35,55) |
| 1-3 | (21,30,50) |
| 2-4 | (28,44,58) |
| 2-6 | (25,43,55) |
| 3-4 | (31,45,52) |
| 3-5 | (24,37,47) |
| 4-7 | (30,47,50) |
| 5-7 | (27,37,50) |
| 6-7 | (35,52,65) |

Based on the activity and activity duration using the triangular fuzzy number
The network diagram is the following:

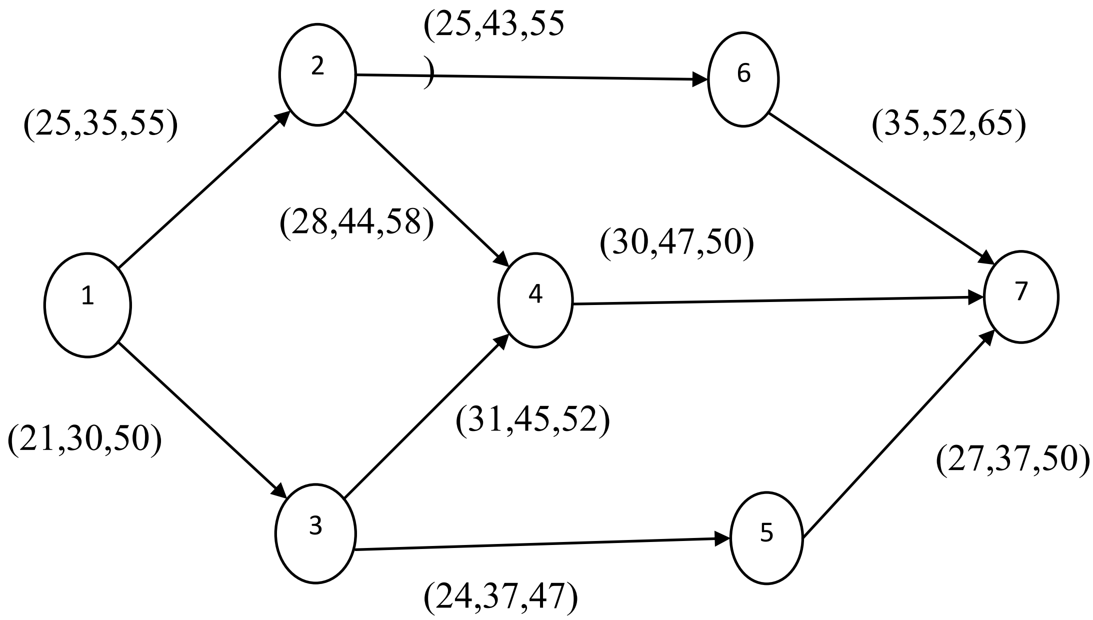


**Figure 2.** network diagram

4.1 Based on the Haar ranking method, all the activity duration changed in to the crisp values using the formula R ( a, b, c) = $\frac{a+2b+c}{4}$.

using the above formula,

Case 1: we have R (25,35,55) = $\frac{25+2(35)+55}{4}$ = 37.5

Case 2: similarly, R (21,30,50) = $\frac{21+2(30)+50}{4}$ = 32.75

Do the process until we get R (35,52,65) = $\frac{35+2(52)+65}{4}$ = 51

The following is the network diagram using the Haar ranking Method:

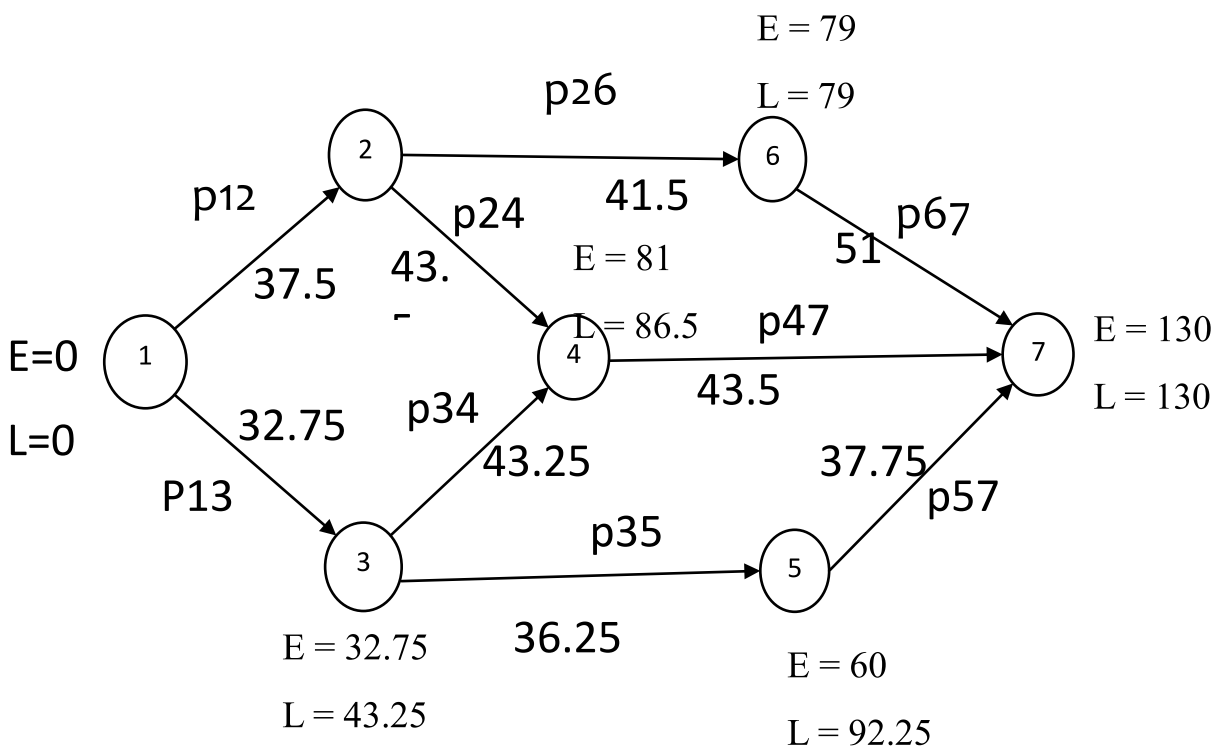


**Figure 3.** network diagram using the Haar ranking method

The following table is the Critical path using the Forward Pass Computation and Backward Pass Computation followed by Haar ranking method.

| Activity | Duration | Starting Time | Finishing Time |
|---|---|---|---|
| 1-2 | (25,35,55) | 0 | 37.5 |
| 1-3 | (21,30,50) | 0 | 32.75 |
| 2-4 | (28,44,58) | 37.5 | 86.5 |
| 2-6 | (25,43,55) | 37.5 | 79 |
| 3-4 | (31,45,52) | 32.75 | 86.5 |
| 3-5 | (24,37,47) | 32.75 | 60 |
| 4-7 | (30,47,50) | 81 | 130 |
| 5-7 | (27,37,50) | 60 | 130 |
| 6-7 | (35,52,65) | 51 | 130 |

Here we have Critical path is$1 \rightarrow 2 \rightarrow 6 \rightarrow 7$

### 4.2 Centroid Ranking Method

Based on the Centroid ranking method, all the activity duration changed in to the crisp values using the formula $G_a = \left( \frac{a+b+c}{3}, \frac{w}{3} \right)$

using the above formula,

Case 1: we have G (25,35,55) = $\left( \frac{25+35+55}{3} \right) \left( \frac{1}{3} \right)$, w=1= 12.77

Case 2: similarly, R (21,30,50) = 14.98

Do the process until we get R (35,52,65) =43.31

The following is the network diagram using the Centroid ranking Method

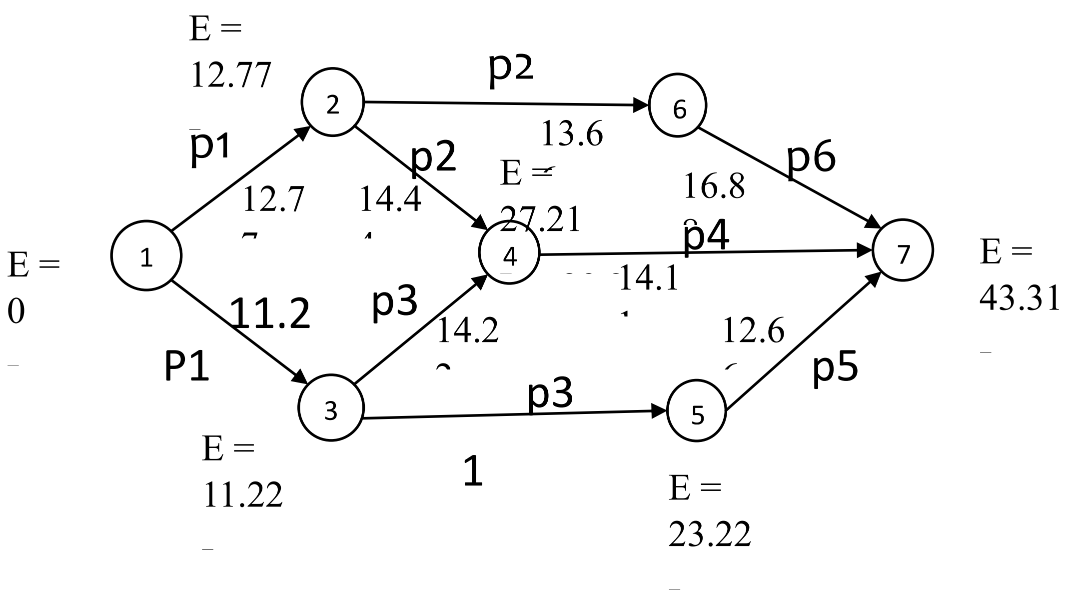


**Figure 4.** network diagram using the Centroid ranking method

The following table is the Critical path using the Forward Pass Computation and Backward Pass Computation followed by Centroid ranking method.

| Activity | Duration | Starting Time | Finishing Time |
|---|---|---|---|
| 1-2 | (25,35,55) | 0 | 12.77 |
| 1-3 | (21,30,50) | 0 | 14.98 |
| 2-4 | (28,44,58) | 12.77 | 29.92 |
| 2-6 | (25,43,55) | 12.77 | 26.43 |
| 3-4 | (31,45,52) | 11.22 | 29.2 |
| 3-5 | (24,37,47) | 11.22 | 30.65 |
| 4-7 | (30,47,50) | 27.21 | 43.31 |
| 5-7 | (27,37,50) | 23.22 | 43.31 |
| 6-7 | (35,52,65) | 26.43 | 43.31 |

Here we have Critical path is $1 \rightarrow 2 \rightarrow 6 \rightarrow 7$

**4.3 Robust Ranking Method**

Based on the Robust ranking method, all the activity duration changed in to the crisp values using the formula $R(a) = 0.5\int_0^1 \left(a_\alpha^L, a_\alpha^U\right) d\alpha$

using the above formula,

Case 1: we have R (12) = 0.5 $\int_0^1 (80 - 10\alpha) d\alpha$

R(12)=37.5

Case 2: similarly, R (13) =32.75

Do the process until we get

The following is the network diagram using the Robust ranking Method

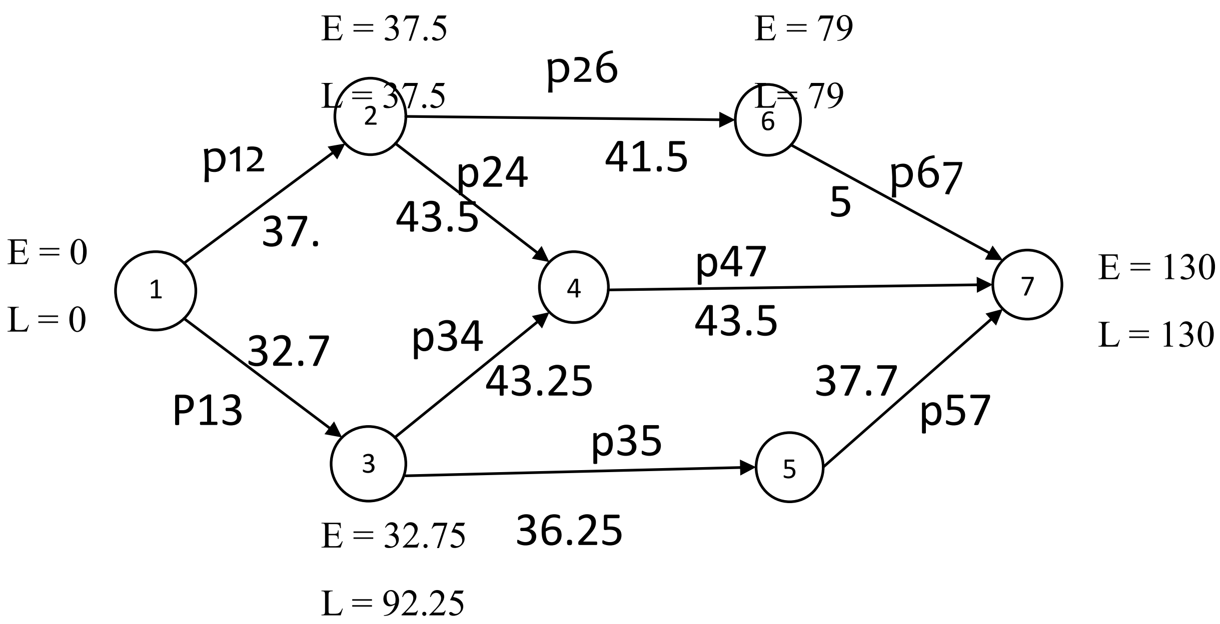


**Figure 5.** network diagram using the Robust ranking method

The following table is the Critical path using the Forward Pass Computation and Backward Pass Computation followed by Robust ranking method.

| Activity | Duration | Starting Time | Finishing Time |
|---|---|---|---|
| 1-2 | (25,35,55) | 0 | 37.5 |
| 1-3 | (21,30,50) | 0 | 32.75 |
| 2-4 | (28,44,58) | 37.5 | 86.5 |
| 2-6 | (25,43,55) | 37.5 | 79 |
| 3-4 | (31,45,52) | 32.75 | 86.5 |
| 3-5 | (24,37,47) | 32.75 | 60 |
| 4-7 | (30,47,50) | 81 | 130 |
| 5-7 | (27,37,50) | 60 | 130 |
| 6-7 | (35,52,65) | 51 | 130 |

Here we have Critical path is $1 \to 2 \to 6 \to 7$

## 5. CONCLUSION

In this paper for Finding Critical path, here three methods are used Critical path is obtained by connecting values after solving this method using triangular fuzzy number. While comparing these methods Robust ranking technique and Haar ranking method gives same values and same path but in case of centroid ranking method it gives same path with different values. After compared these three methods, the Haar ranking method is the best method for treating shortest path problem by using triangular fuzzy number.

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