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# Improvised construction management activity scheduling using proposed Cheng's fuzzy entropy-analytical node activity hierarchy process (ANAHP)

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**Abstract**
In this paper, a new project management technique is modified for encompassing decision uncertainty. The previous method proposed is called Analytical Node Activity Hierarchy Process (ANAHP), with current study a Fuzzy Cheng's technique is being introduced namely Cheng's entropy technique. The process involves node network analysis along with a provision of fuzzy decision making of available alternative for an activity based on various criteria defined by the decision maker. For construction projects some of these criteria can be cost of the construction, time duration of the completion of work and durability of the component or reliability of the materials. For devising the method, a parametric model problem in terms of variables is described with corresponding independent variables varying from problem to problem. The modified method can help in improving the efficiency and dimensionality of the project management process while compensating for uncertainties. At the end of the paper a scope of the future studies is also mentioned that opens doors to new and more accurate techniques that can also be adopted or modified as per the need for the construction industry.

**Keywords:** Cheng's Fuzzy Techniques, Fuzzy Entropy technique, Construction Management, Node Network, Activity Scheduling, Analytical Hierarchy Process (AHP), Analytical Node Activity Hierarchy Process (ANAHP).

## 1. Introduction

The study involves an approach to integrate modern management technique in construction management and to study a model problem and validate the proposed model for its flexibility of application. The research also aims to suggest the best alternatives for the project activities on the basis of criteria like cost, durability and time for completion which can provide basic framework for an integrated solution for a generalized model problem for a future adaption in project management practices. The necessity for this study is depicted as a need for increase in dimensionality of the conventional methods of project management. The conventional methods developed for project management are too old and there is scope for introducing new methods to increase the functionality of these existing methods. A requirement of providing efficient solutions to project management problems is necessary. The processes used for project management yield in management aid in various ways. However there is a missing link in several of these methods that can combine these approach for an efficient output. An example for these missing links is in between Decision making techniques and Project management network technique. To introduce choice making process in the Network formation for a project the dimensionality can be increased drastically as per requirement. Conventional methods does not include necessary provisions or parameters that can take care of real life situations in project management practices. This project aims to introduce the technique of decision making in the project management technique to simulate real life scenarios faced in project management.

**2. Methods & Materials:** Arithmetic Hierarchy Process (AHP) is used for the application of decision making a choice selection. Apart from decision making, a process Node network process is used to solve and integrate the problem parameters. Real life Project Scenario for the problem taken with some parameters is that the data is nearly hypothetical and is taken to approximately simulate real life project management scenario.

The fractions of the cost associated with each activity for the project is generalized to most accurate value. The problem situation taken however gives a framework to apply proposed technique. At the end of the study the conclusion drawn reflects the importance of adapting the modern management techniques and it is shown and proven that integrating several of these techniques can help in increasing the efficiency of project management. At the end of this study a new technique for project management is proposed named as Analytical Node Activity Hierarchy Process (ANAHP), which is an integration of Node Network Process and Decision making technique as Arithmetic Hierarchy Process.

**2.1 Modern Management Techniques used:** Conventional method of project management involves network formation in a sequential order and connecting all activities with links establishing inter activity relationships. However the process of decision making and active feedback is not included in the network activity diagram. This study aims to introduce an integration of decision making hierarchy process in the Node Network diagram. The process of decision making is a modern technique that uses various modern methods like AHP, Fuzzy decision making, Cheng's Entropy technique, Cheng's Extent analysis & Buckley's Fuzzy AHP method. Introduction and integration of these modern methods will increase the dimensionality of the Node Network management system to decision integrated planning. The managers can schedule and alongside choose alternatives available for any specific activity for maximum efficiency in terms of cost reduction and high quality.

For the study following methods are used and integrated:
1). Node Network Management.
2). Analytical Hierarchy Process.
3). Proposed Cheng's Entropy Process.

**2.2 Project Definition:** The project for the application demonstration is taken as a variable based dummy activity problem. These variables are independent of each other and solely depends on the type of problem with their corresponding activities.

**Table 1:** Model problem details

| Activity | Specification | Previous Activity | Activity Choices |
|---|---|---|---|
| A | Activity 1 | - | Alternative 1 |
| B | Activity 2 | - | Alternative 2 |
| C | Activity 3 | A,B | Alternative 3 |
| D | Activity 4 | C | Alternative 4 |
| E | Activity 5 | C | Alternative 5 |
| F | Activity 6 | D | Alternative 6 |
| G | Activity 7 | E | Alternative 7 |

**2.3 Conventional Project Management Process:** A project is a well-defined task which has a definable beginning and a definable end and requires one or more resources for the completion of its constituent activities, which are interrelated and which must be accomplished to achieve the objectives of the project. Project management is evolved to coordinate and control all project activities in an efficient and cost effective manner. The salient features of a project are:

- A project has identifiable beginning and end points.
- Each project can be broken down into a number of identifiable activities which will consume time and other resources during their completion.
- A project is scheduled to be completed by a target date.
- A project is usually large and complex and has many interrelated activities.
- The execution of the project activities is always subjected to some uncertainties and risks.

**2.4 Network Techniques**

The network techniques of project management have developed in an evolutionary way in many years. Up to the end of 18th century, the decision making in general and project management in particular was intuitive and depended primarily on managerial capabilities, experience, judgment and academic background of the managers. It was only in the early of 1900's that the pioneers of scientific management, started developing the scientific management techniques. The forerunner to network techniques, the Gantt chart was developed, during World War I, by Henry L Gantt, for the purpose of production scheduling. An example of Gantt chart is shown in Figure 1. The Gantt chart was later modified to bar chart, which was used as an important tool in both the project and production scheduling. The bar charts, then developed into milestone charts, and next into network techniques (such as CPM and PERT).

**2.5 Network Construction**

A network is the graphical representation of the project activities arranged in a logical sequence and depicting all the interrelationships among them. A network consists of activities and events.

**Activity**

An activity is a physically identifiable part of a project, which consumes both time and resources. Activity is represented by an arrow in a network diagram. The head of an arrow represents the start of activity and the tail of arrow represents its end. Activity description and its estimated completion time are written along the arrow. An activity in the network can be represented by a number of ways: (i) by numbers of its head and tail events (i.e. 10-20 etc.), and (ii) by a letter code (i.e. A, B etc.). All those activities, which must be completed before the start of activity under consideration, are called its predecessor activities. All those activities, which have to follow the activity under consideration, are called its successor activities. An activity, which is used to maintain the pre-defined precedence relationship only during the construction of the project network, is called a dummy activity. Dummy activity is represented by a dotted arrow and does not consume any time and resource. An unbroken chain of activities between any two events is called a path.

**Application of Node Activity Process**

The model problem is solved below by conventional Node Network process for finding logical relationship between the activities in a systematic order.

**Table 2:** Predecessor relation of activity

| Activity | Specification | Previous Activity |
|---|---|---|
| A | Activity 1 | - |
| B | Activity 2 | - |
| C | Activity 3 | A,B |
| D | Activity 4 | C |
| E | Activity 5 | C |
| F | Activity 6 | D |
| G | Activity 7 | E |

Using the predecessor relationship provided, a Node network diagram can be prepared.

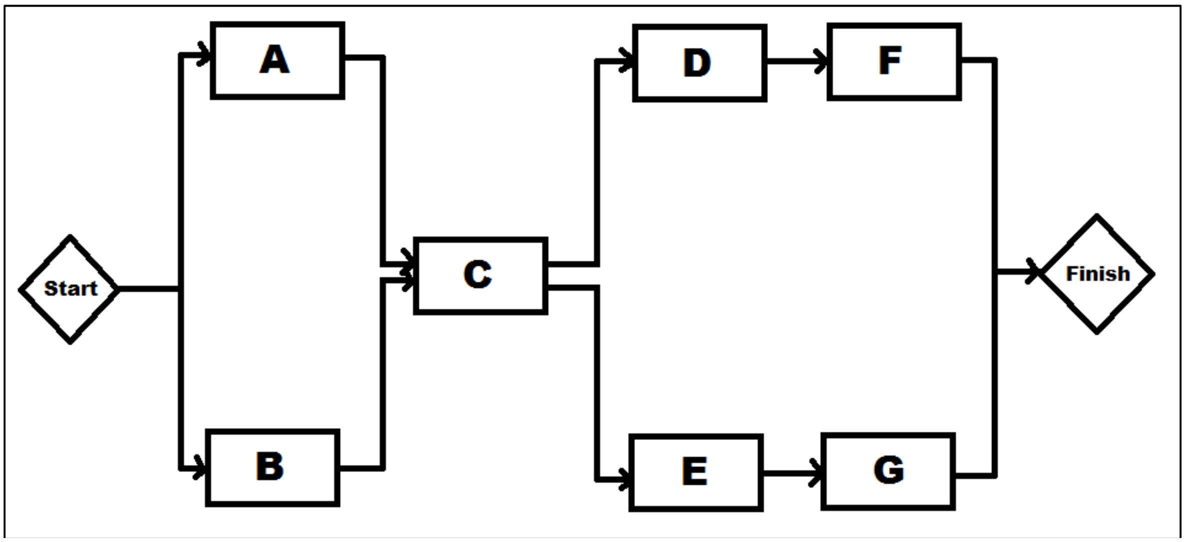


**Fig 1:** Node network solution of problem

**Disadvantage of the conventional process:** The method doesn't take care of the choices provided with each activity. The dimensionality of the problem is reduced to 1 (Minimum cost or Minimum time). Dimensional variable like durability and comparison of alternatives is not included in the process.
Introducing the Integration of Hierarchy process in node network process to increase the dimensionality of the whole process.

**2.6 Analytic Hierarchy Process (AHP):** The analytical hierarchy process was developed primarily by Saaty (1980). AHP is a type of additive weighting method. It has been widely reviewed and applied in the literature, and its use is supported by several commercially available, user-friendly software packages. Decision makers often find it difficult to accurately determine cardinal importance weights for a set of attributes simultaneously. As the number of attributes increases, better results are obtained when the problem is converted to one of making a series of pairwise comparisons. AHP formalizes the conversion of the attribute weighting problem into the more tractable problem of making a series of pairwise comparisons among competing attributes. AHP summarizes the results of pairwise comparisons in a "matrix of pairwise comparisons." For each pair of attributes, the decision 8 C. Kahraman maker specifies a judgment about "how much more important one attribute is than the other."
Each pairwise comparison requires the decision maker to provide an answer to the question: "Attribute A is how much more important than Attribute B, relative to the overall objective"
The Analytic Hierarchy Process (AHP) is a multicriteria decision aiding method based on a solid axiomatic foundation. AHP is a systematic procedure for dealing with complex decision making problems in which many competing alternatives (projects, actions, scenarios) exist [Forman and Selly (2002) [6], Saaty and Vargas (1994), Saaty (1990), Saaty (1995), Vargas (1990)]. The alternatives are ranked using several quantitative and/or qualitative criteria, depending on how they contribute in achieving an overall goal.

**Table 3:** Pairwise comparison matrix A of alternatives $P_i$ with respect to criterion K

| K | $P_1$ | $P_2$ | … | $P_n$ |
|---|---|---|---|---|
| $P_1$ | 1 | $a_{12}$ | … | $a_{1n}$ |
| $P_2$ | $1/a_{12}$ | 1 | … | $a_{2n}$ |
| … | … | … | … | … |
| $P_n$ | $1/a_{1n}$ | $1/a_{2n}$ | … | 1 |

AHP is based on a hierarchical structuring of the elements that are involved in a decision problem. The hierarchy incorporates the knowledge, the experience and the intuition of the decision-maker for the specific problem. The simplest hierarchy consists of three levels. On the top of the hierarchy lies the decision's goal. On the second level lie the criteria by which the alternatives (third level) will be evaluated. In more complex situations, the main goal can be broken down into sub-goals or/and a criterion (or property) can be broken down into sub-criteria. People who are involved in the problem, their goals and their policies can also be used as additional levels.

The hierarchy evaluation is based on pairwise comparisons. The decision maker compares two alternatives $A_i$ and $A_j$ with respect to a criterion and assigns a numerical value to their relative weight. The result of the comparison is expressed in a fundamental scale of values ranging from 1 ($A_i$, $A_j$ contribute equally to the objective) to 9 (the evidence favoring $A_i$ over $A_j$ is of the highest possible order of affirmation). Given that the n elements of a level are evaluated in pairs using an element of the immediately higher level, an n × n comparison matrix is obtained (Table 2). If the immediate higher level includes m criteria, m matrixes will be formed. In every comparison matrix all the main diagonal elements are equal to one ($a_{ii} = 1$) and two symmetrical elements are reciprocals of each other ($a_{ij} \times a_{ji} = 1$).

Since n(n-1)/2 pairwise comparisons are required to complete a comparison matrix, mn(n-1)/2 judgments must be made to complete the evaluation of the n elements of a level using as criterion the m elements of the immediately higher level. For large evaluations, the number of comparisons required by the AHP can be somewhat of a burden. For example, if 5 alternatives are to be evaluated, in a model containing 20 criteria, at least 10 × 20 = 200 judgments must be made.

The decision-maker's judgments may not be consistent with one another. A comparison matrix is consistent if and only if $a_{ij} \times a_{jk} = a_{ik}$ for all i, j, k. AHP measures the inconsistency of judgments by calculating the consistency index CI of the matrix

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad \text{Eq.1}$$

Where $\lambda_{max}$ is the principal eigenvalue of the matrix.

The consistency index CI is in tum divided by the average random consistency index RI to obtain the consistency ratio CR.

$$CR = \frac{CI}{RI} \qquad \text{Eq.2}$$

The RI index is a constant value for an nxn matrix, which has resulted from a computer simulation of n × n matrices with random values from the 1-9 scale and for which $a_{ij} = 1/a_{ji}$. If CR is less than 5% for a 3 × 3 matrix, 9% for a 4 × 4 matrix, and 10% for larger matrices, then the matrix is consistent.

Once its values are defined, a comparison matrix is normalized and the local priority (the relative dominance) of the matrix elements with respect to the higher level criterion is calculated. The overall priority of the current level elements is calculated by adding the products of their local priorities by the priority of the corresponding criterion of the immediately higher level. Next, the overall priority of a current level element is used to calculate the local priorities of the immediately lower level which use it as a criterion, and so on, till the lowest level of the hierarchy is reached. The priorities of the lowest level elements (alternatives) provide the relative contribution of the elements in achieving the overall goal.

Note that the AHP also allows group decision making. Each member of the group provides separately his own judgments according to his experience, values and knowledge. If the group has achieved consensus on some judgment, only that judgment is registered. If during the process it is impossible to arrive at a consensus on a judgment, the group may use some voting technique, or may choose to take the "average" of the judgments, that is the geometric mean of the judgments. The group may decide to give all group members equal weight, or the group members could give them different weights that reflect their position in the project.

**3. Analytical Node Activity Hierarchy Process (ANAHP):** The results from both the process can be integrated in this newly introduced ANAHP technique. This allows the introduction of decision making in the process of node activity process.

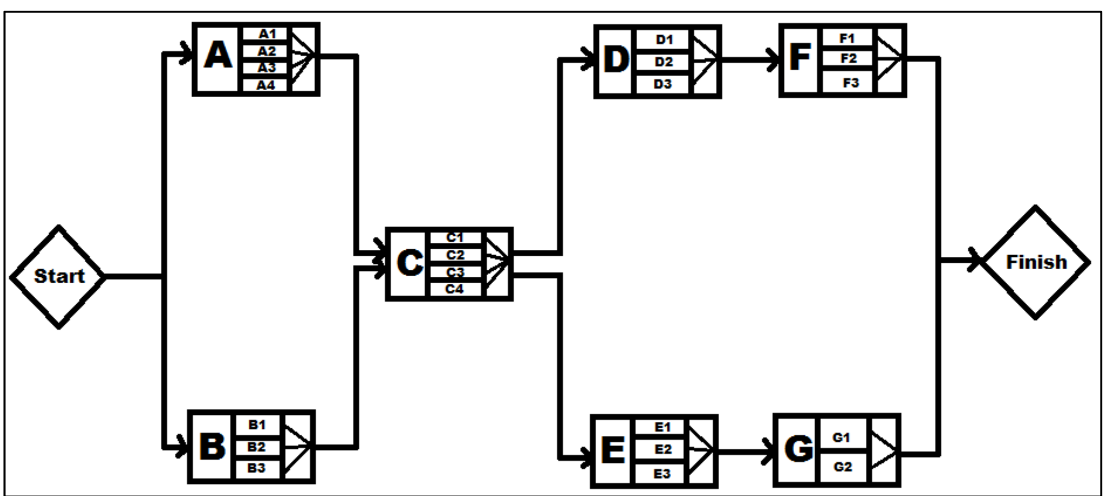


**Fig 2:** Integrated Analytical Node Activity Hierarchy Process for problem

The ranks obtained from the AHP technique is used to choose only one best alternative for the individual activity. This converges the output for the ANAHP technique to that of the Node network process. After the convergence of the ANAHP network, conventional operations to find Critical path and project duration can be applied for efficient project management.

The converged output of ANAHP technique is shown in below figure:

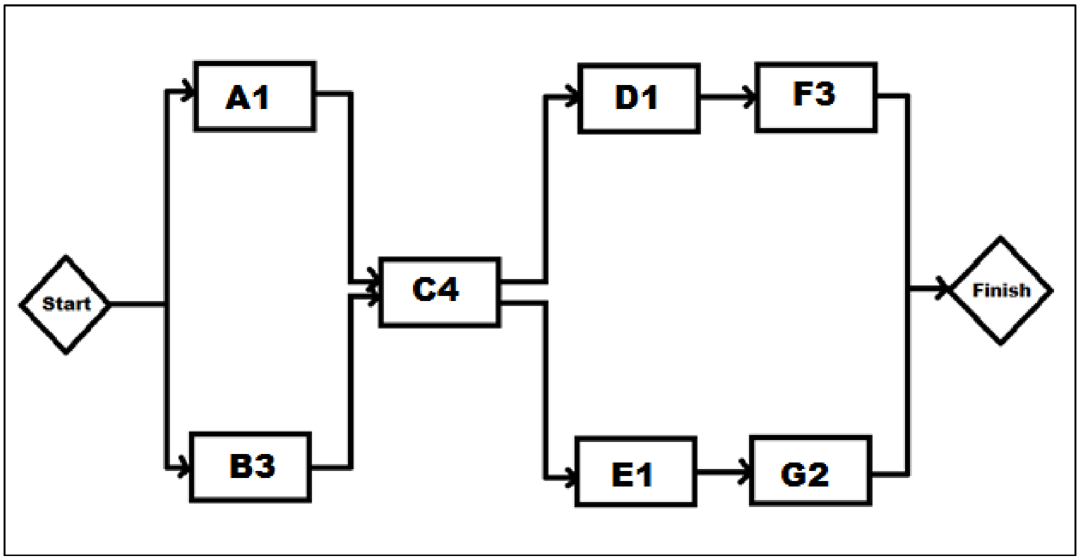


**Fig 3:** Converged output of ANAHP as a conventional node network

**4. Introduction of Cheng's Fuzzy Entropy Technique:** Although this method is being introduced for the first time as an integrated process, this can only be applied for Node Network process. There is no provision for arrow network integration as of now. The Analytical Node Activity Hierarchy Process (ANAHP) can be used to develop hybrid software that can handle activity scheduling and decision making process parallel in a single and integrated way. Various more method can be used as a substitute for Analytical Hierarchy Process. Thus for incorporating uncertainties in decision variables, the modified ANAHP method is introduced. Best suited method for problems like construction projects is considered out to be Cheng's Entropy Process based on previous literature.

The following method describes the Cheng's entropy method of multi-criteria decision analysis. The fuzzy scale for the Chang's entropy method is defined for a given difference in rating value of any alternative or any criteria. A fuzzy triangular function is taken for defining a fuzzy scale. The following table shows the fuzzy scale associated with the method:

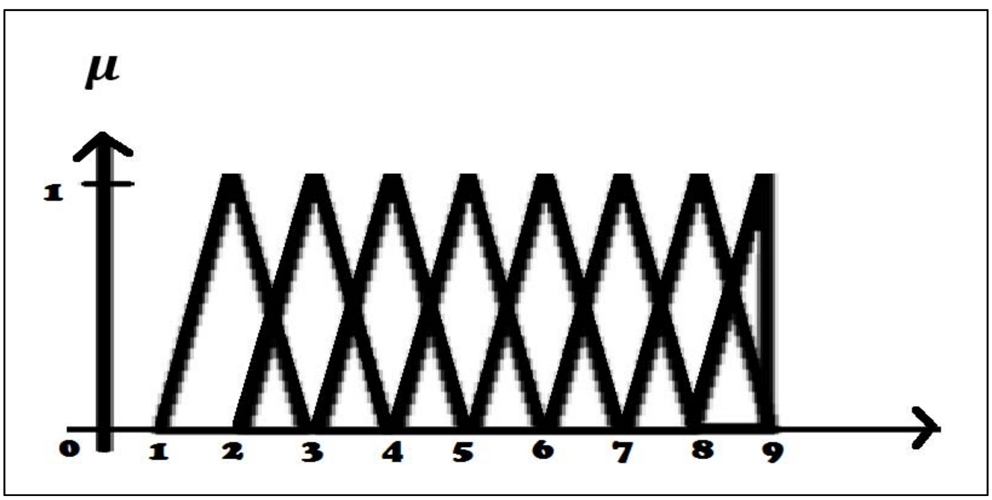


**Fig 4:** Fuzzy Membership function; Cheng's Entropy/Extent Method

**Table 4:** Fuzzy Score Scale corresponding to rating difference value

| Diff. (Ci-Cj) | L. Scale (Ci) | F. Scale | Diff. (Ci-Cj) | L. Scale (Cj) | F. Scale |
|---|---|---|---|---|---|
| 8 | Extremely Important | 8,9,9 | -8 | Extremly Important | .11,.11,.12 |
| 7 | Highly Important | 7,8,9 | -7 | Highly Important | .11,.12,.14 |
| 6 | Very Important | 6,7,8 | -6 | Very Important | .12,.14,.16 |
| 5 | Slightly More Imp. | 5,6,7 | -5 | Slightly More Imp. | .14,.16,.20 |
| 4 | Weakly More Imp. | 4,5,6 | -4 | Weakly More Imp. | .16,.20,.25 |
| 3 | Important | 3,4,5 | -3 | Important | .20,.25,.33 |
| 2 | Slightly Imp. | 2,3,4 | -2 | Slightly Imp. | .25,.33,.50 |
| 1 | Weakly Imp. | 1,2,3 | -1 | Weakly Imp. | 0.33,0.50,1 |
| 0 | Equally Imp. | 1,1,1 | 0 | Equally Imp. | 1,1,1 |

Shannon entropy, H, which is applicable only to probability measures, assumes the following form in evidence theory (Klir and Yan, 1995):

$$H(m) = -\sum_{j=1}^{n} m(\{x\})log_2 m(\{x\})$$

This function, which forms the basis of classic information theory, measures the average uncertainty associated with the prediction of outcomes in a random experiment. Its range is

$$[0, log_2|X|].$$

Clearly, H(m) = 0.
When m({x}) = 1 for some x$\in X; H(m) = log_2|X|$, when m defines the uniform probabilities distribution on X(i.e., (m{x}) = 1/|X|, $\forall x \in X$).
The principle of maximum uncertainty is well developed and broadly utilized within classic information theory, where it is called the principle of maximum entropy.
Cheng's [1996] evaluation model can be described as given below:
Step 1. Construct a hierarchy structure for any problem.
Step 2. Build membership function of judgment criteria.
Step 3. Compute the performance score.
Step 4. Utilize fuzzy AHP method and entropy concepts to calculate aggregate weights.
The computational procedure of this decision-making methodology is summarized as follows.
To compare the performance scores, we can use symmetric triangular fuzzy numbers$\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ to indicate the relative strength of the elements in the hierarchy matrix.
To assemble the total fuzzy judgement matrix $\tilde{A}$, we can multiply the fuzzy subjective weight vector W~ with the corresponding column of fuzzy judgement matrix $\tilde{X}$. Thus, we get

$$\tilde{A} = \begin{bmatrix} \tilde{w}_1 \otimes \tilde{x}_{11} & \tilde{w}_2 \otimes \tilde{x}_{12} & \cdots & \tilde{w}_n \otimes \tilde{x}_{1n} \\ \tilde{w}_1 \otimes \tilde{x}_{21} & \tilde{w}_2 \otimes \tilde{x}_{22} & \cdots & \tilde{w}_n \otimes \tilde{x}_{22} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{w}_1 \otimes \tilde{x}_{n1} & \tilde{w}_2 \otimes \tilde{x}_{n2} & \cdots & \tilde{w}_n \otimes \tilde{x}_{nn} \end{bmatrix}$$

$$\tilde{A} = \begin{bmatrix} \tilde{w}_1 \otimes \tilde{x}_{11} & \cdots & \tilde{w}_n \otimes \tilde{x}_{1n} \\ \cdots & \cdots & \cdots \\ \tilde{w}_1 \otimes \tilde{x}_{n1} & \cdots & \tilde{w}_n \otimes \tilde{x}_{nn} \end{bmatrix}$$

Now fuzzy number multiplications and additions using the interval arithmetic and $\alpha$ cuts are made, and Eq. (30) is obtained.

$$\tilde{A}_\alpha = \begin{bmatrix} [a_{11l}^\alpha, a_{11n}^\alpha] & \cdots & [a_{1nl}^\alpha, a_{1nu}^\alpha] \\ \vdots & \ddots & \vdots \\ [a_{n1l}^\alpha, a_{n1u}^\alpha] & \cdots & [a_{nn1}^\alpha, a_{nnu}^\alpha] \end{bmatrix}$$

Where $a_{ijl}^\alpha = w_{il}^\alpha x_{ijl}^\alpha, a_{iju}^\alpha = w_{iu}^\alpha x_{iju}^\alpha, for\ 0 < \alpha \leq 1$ and all i, j.

Now the degree of satisfaction of the judgment Â will be estimated. When $\alpha$ is fixed, we will set the index of optimism λ by the degree of the optimism of a decision maker. A larger λ indicates a higher degree of optimism. The index of optimism is a linear convex combination it is explained by

$$\hat{a}_{ij}^\alpha = (1-\lambda)a_{ijl}^\alpha + \lambda a_{ijl}^\alpha, \forall\, \lambda \in [0,1].$$

Thus we have,

$$\hat{A} = \begin{bmatrix} \hat{a}_{11}^\alpha & \hat{a}_{12}^\alpha & \cdots & \hat{a}_{1n}^\alpha \\ \hat{a}_{21}^\alpha & \hat{a}_{22}^\alpha & \cdots & \\ \vdots & \vdots & \ddots & \vdots \\ \hat{a}_{n1}^\alpha & \hat{a}_{n2}^\alpha & \cdots & \hat{a}_{nn}^\alpha \end{bmatrix}$$

Where $\hat{A}$ is a precise judgment matrix.
The entropy must be first calculated by using the relative frequency of the Eq. and the entropy formula of Eq., i.e.,

$$\begin{bmatrix} \frac{a_{11}}{s_1} & \frac{a_{12}}{s_1} & \cdots & \frac{a_{1n}}{s_1} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{a_{n1}}{s_n} & \frac{a_{n2}}{s_n} & \cdots & \frac{a_{nn}}{s_n} \end{bmatrix} = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{n1} & f_{n2} & \cdots & f_{nn} \end{bmatrix}$$

Where

$$s_k = \sum_{j=1}^{n} a_{kj}$$

We can use this equation to calculate the entropy, i.e.

$$H_1 = -\sum_{j=1}^{n} (f_{1j}) log_2 (f_{1j})$$

$$H_2 = -\sum_{j=1}^{n} (f_{2j}) log_2 (f_{2j})$$

.
.

$$H_n = -\sum_{j=1}^{n} (f_{nj}) log_2 (f_{nj})$$

Where $H_i$ is i[th] entropy value.
The entropy weights can be determined by using Eq.

$H = \frac{H_i}{\sum_{j=1}^{n} H_j}$, i= 1, 2………n

**5. Conclusion:** It is been shown that how the process of decision making can be incorporated in network scheduling more efficiently by introducing fuzzy techniques that compensate for the decision variable uncertainties. Further study is still required in the field of fuzzy techniques to introduce more advanced method of fuzzy decision making and compare them for their effectiveness in various types of scheduling problems.

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