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PROJECT MANAGEMENT: NETWORK BASED MANAGEMENT SYSTEM WITH THE SUPPORT OF FUZZY LOGIC

ファジィ理論を取り入れた建設管理計画

*Meor Aziz Osman**, *Hajime INAMURA***

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1. INTRODUCTION

Due to increased amount of complexity in handling projects, more specialize techniques are required to plan and control projects. Artificial intelligence (AI), especially fuzzy logic (FL) has brought a new dimension in networking. In dealing with uncertainty, previous network planning techniques are based on stochastic models. Theoretically fuzzy models are closer to reality but not well established especially in project construction. The impact of stochastic and fuzzy version of PERT is illustrated via numerical example to justify a more practical and realistic network schedule. By developing an easy operated expert system, the complexity underlying fuzzy concept can be overcome and benefit end users.

2. PREVIOUS METHODS

Optimistic and pessimistic duration are based on judgment and experience leading to unfounded values. Secondly, the current FL math function proves to be more difficult, degenerates into additional continuous points. Thirdly, conventional methods, linguistic values are presented graphically invoking interpretation difficulties. These complexity attributes to impracticality.

3. APPROACH AND METHODOLOGY

A recently completed project was selected as a case study and acts as control. Two principles areas were studied upon; activity duration and resource allocation aspect. **Fig.1** shows the flowchart of research. Initially, simulation will be done to the small project (8 activities;13months duration) and positive results warrants further application to the complete network (20 activities;16.5 months duration). The so called small project is a few selected activities from the complete project.

*Tohoku Unversity, Student Member (M2), Dept. of Human-Social and Information Science.
**Tohoku University, Staff Member (Professor), Dept. of Human-Social and Information Science.
(〒:Aoba, Aoba-ku, Sendai 980; TEL: 022-217-7497)

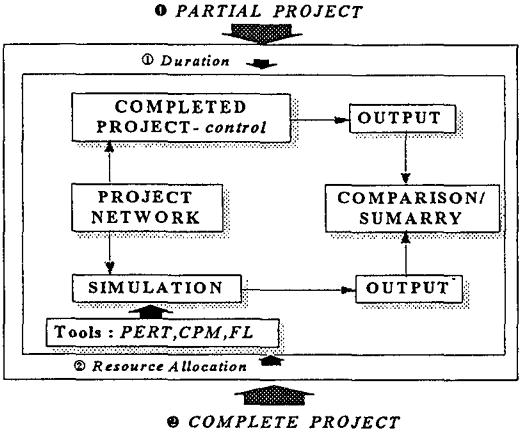

Fig.1: Flowchart of Research

4. FIRST STAGE: ACTIVITY DURATION

Fig.2 shows the detail concept and flow adopted for this stage. PERT and FL mathematical function were calculated base on the same activity duration distribution. PERT stochastic variable modeled activity duration as independent and identical distributed random variables with beta distribution (optimistic - a , the most likely - m , pessimistic-b). These values are estimated strictly based on site engineer's experience.

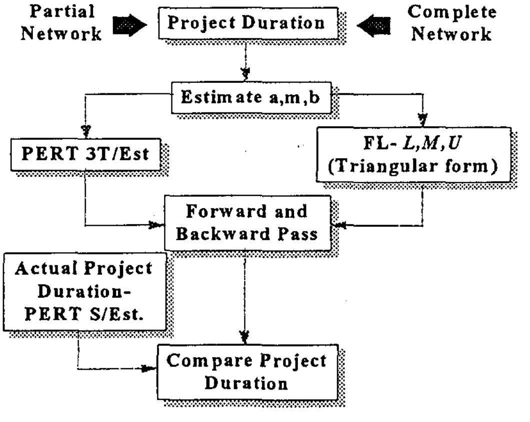

Fig.2: Concept and Flow of Stage 1

To compare and having similar distribution as PERT, fuzzy triangular membership function was adopted as shown in **Fig.3** whereby with $[l,u]$ as the base and the top value of 1 at m.

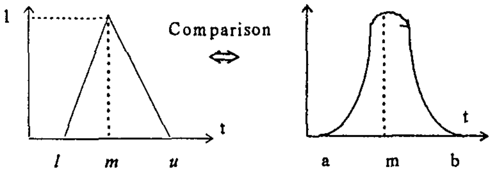

Fig. 3: PERT *Beta* and Fuzzy Triangular Function

By using fuzzy numbers and operators, performing forward and backward operation with current method to calculate the expected completion period, it becomes progressively difficult with each $\widetilde{\max}$ (or $\widetilde{\min}$) taken since the $\widetilde{ES}$ (or $\widetilde{LS}$) degenerates into fuzzy numbers having additional discontinuous points. With modified fuzzy numbers, discrete max. (or min.) are adopted for *ES* (or *LS*). Applying to multiple activity to node, additional discontinuous is neglected, keeping a simple triangular form. **Fig. 4** shows the condition.

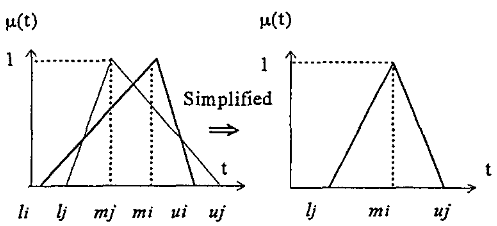

Fig. 4: Adoption of Simple Triangular Form

For earliest time by using the relationship:

$$\tilde{t}_j = \max_{i \in B_j} (\tilde{t}_j + \tilde{d}_{ij}) \quad \ldots\ldots\ldots\ldots\ldots(1)$$

the lower value *L(d)*, modal value *M(d)*, and upper value *U(d)* of maxima can be written as follows and their values can be calculated separately via a longest path algorithm.

$$L(\tilde{t}_j) = \max_{i \in Bj} [(\tilde{t}_i) + L(\tilde{d}_{ij})] \quad \ldots\ldots\ldots\ldots\ldots(2)$$

$$M(\tilde{t}_j) = \max_{i \in B_j} [M(\tilde{t}_i) + M(\tilde{d}_{ij})] \quad \ldots\ldots\ldots(3)$$

$$U(\tilde{t}_j) = \max_{i \in Bj} [U(\tilde{t}_i) + U(\tilde{d}_{ij})] \quad \ldots\ldots\ldots\ldots(4)$$

Similarly for latest time, inverse of fuzzy addition is executed with the min. latest time selected . Only results for the complete project using both PERT and FL are shown as in **Fig. 5**, earliest time for the project. FL modification method shows a reduction of overall completion period by 15% equivalent to 2.5 months) as compared to PERT and the actual completion of project. By preserving the original shapes of component fuzzynumbers, modeling accuracy is sacrificed for computational ease. However, compared to PERT , it proves to be significant and its applications depend on individual project status.

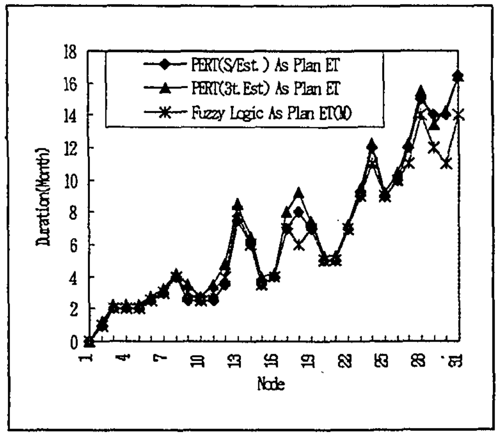

Fig. 5: Earliest Time for Complete Project

5. STAGE 2-RESOURCE ALLOCATION

To substitute optimistic and pessimistic durations for the often used unfounded values based on human judgment. Experienced schedulers increase /decrease extra time to account for the combined impact of various factors. Estimation were merely based on past experience in similar situation. The concept and flow is as shown in **Fig.6**.

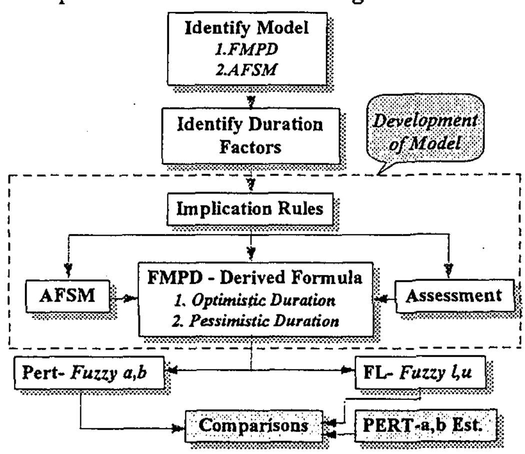

Fig.6: Concept and Flow of Stage 2

Inference mechanism and fuzzy modus ponens deduction technique (FMPD) concurrent with the angular fuzzy set models (AFSM) were techniques recently proposed and only basic ideas were outlined . Further development is required.

SELECTION OF MODEL

Apart from applying FMPD technique to evaluate the impact of different factors on activity duration, additional fuzzy logic operations such as truth functional modification (TFM) and inverse functional modification (ITFM) are also intergrated. Linguistic values are represented by AFSM. Combination of these techniques, partial matching an evidence with a rule can be done with relative ease through a simple calculation from derived formula.

Fuzzy Modus Ponen Deduction

The purpose is to find the membership function of a linguistic value (B') in an implication proposition under conditional proposition. Consider the following proposition:

Proposition: IF FL is *very convincing* THEN its performance is *good*, is *true*. If FL is *fairly convincing* is *true*, what is the conclusion?

Can be written as:

Ant. 1: [a is A] $\supset$ [b is B] is τ_1.......(1)

Ant.2: [a is A'] is τ_2.......................(2)

Cons.: [b is B] is τ_B and [b is B']; $\tau_B \supset T$

Membership function expression:

$$\Phi_{A'}(z) = \Phi_{\tau A} [\Phi_A(z)]$$

Using and expanding the basis of membership function as before and apply TFM and ITFM concept, a derived equation is obtained:

$$\tan(B') = \frac{\tan B \tan\tau_1 \tan A' \tan\tau_2}{\tan\tau_1 \tan A + \tan\tau_2 \tan A'} \quad \text{...........(3)}$$

Result: Conclusion is " the performance is between *fairly good* and *undecided*" ($\tau_1,\tau_2 = \pi/4$,b,A= $3\pi/8$, A'= $\pi/8$). B, A, A', τ are angles of linguistic values.

Angular Fuzzy Set Model

The angular model used a semicircle on the right hand side of the vertical axis to represent the values in a universe of discourse. Membership value is a function of the angle thus solving numerically and easier to interpret. Example of AFSM defined in universe of discourse is as shown in **Fig. 7.** The linguistic values are represented by lines with angle α. The horizontal axis and the maximum value is indicated by the line with α=0 and $\alpha=\pi/2$ respectively. The same applies to bottom half of semi-circle but the values are negative.

6. DEVELOPMENT OF MODEL

The *following steps explain the developed* operations.

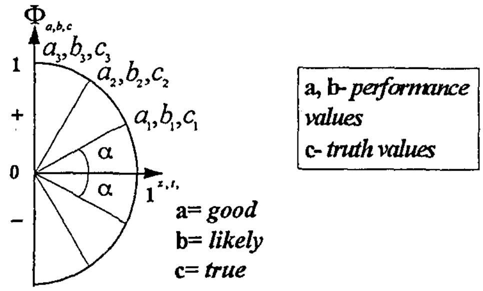

Fig. 7: Fuzzy Angular in Universe of Discourse

1. Consider impact of duration factors to construction activity or activities. **Table 1** illustrates the preferences for the small project adopted. Six duration factors have been identified.

	1	2	3	4	5	6
Duration Activity	Site Condition	Weather Condition	Material Supply	Labor Performance	Equipment Performance	Management Performance
A	●	●		●	●	◎
B	●	●	●	●	●	◎
C	●	●	●	●		◎
D	●	●		●	●	◎
E	●	●	●	●		◎
F	●	●	●	●	●	◎
G	●	●		●	●	◎
H	●	●	●	●	●	◎

Table 1: Selection and Impact of Duration Factors

2. Options for creating implication rules are as shown in **Table 2.** Case 1 with 1 rule, case 2 with 6 rules, case 3 with 36 rules . Case 4 with 10 rules was selected since in intermediate level. These rules are represented by the first antecedent in (1).

Case	All D.F	One D.F	All Act.	One Act.	Comb. Act.
1	●		●		
2		●	●		
3		●		●	
4		●			●

Table 2: Implication Rules Preferences

Taking the example of site condition as the duration factor, the following illustrates part of the implication rules involved.

i. IF site condition is *very good*, THEN the possibility of activities A,B,D to be completed as schedule are *very likely.*

ii. IF site condition is *good*, THEN the possibility of activities E, G, H to be completed as schedule are *very likely.*

3. The values of each factor (evidence) that may have an impact on optimistic and pessimistic duration are chosen based on assessment. Example, construction site is relatively flat terrain, clearing and grubbing still needed but to lesser extent. Thus effect on optimistic duration is fairly good. The same applies to pessimistic duration.

4. The angular FMPD operations are used to calculate the angular value of an activity using equation (3).

5. FMPD's angular values are transformed to actual duration the using sine function with the assumption optimistic and pessimistic duration are limited to ±0.5 of likely duration.

Results for small project based on activity duration and project completion period (Stage 1 and 2) are shown by **Fig. 8 and 9** respectively. It shows mixed characterictics; some concurred, some close proximity, while others having big difference concluding that human judgement amounts to distorted values. Also, using FL math function with FL duration values definitely provides a shorter duration as that to PERT (estimate and FL values).

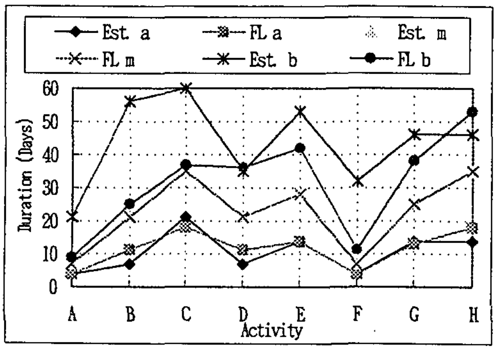

Fig. 8: Comparing Activity Duration

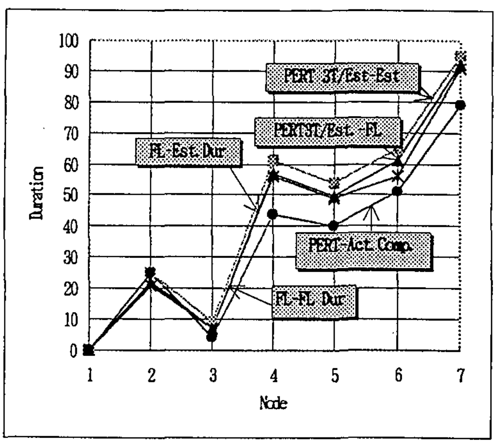

Fig. 9: Project Duration (Earliest Time)

7. **STAGE 3 :KNOWLEDGE - BASED EXPERT SYSTEM**

Creating a simple package without the users understanding of the underlying complexity of fuzzy concept is very much desirable. **Fig. 10** shows the concept and flow intended.

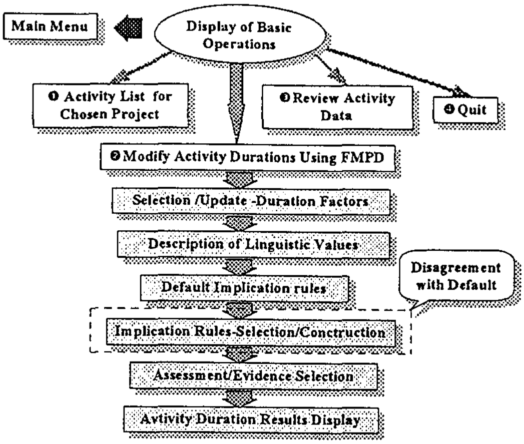

Fig.10: Concept and Flow of Stage 3

8. DISCUSSION

i. In stage 1 , PERT, modeled as beta distribution to cater for uncertainty in activity duration is theoretically valid and effective if it relies on past experience. Discrete max. and min. approach eleviate the complexity and more practical.

ii. In stage 2, the proposed method also has its limitations since the input is subjective. Different values maybe furnish when assessing a construction project. Though optimistic and pessimistic duration can be calculated, they are basically based on the accuracy of estimating the most likely duration. However by adopting the proposed method, the subjectivity is minimized.

iii. Generally, the use of fuzzy logic to determine activity duration is feasible and the usage can perhaps be enhance with the support of KBES which is the focus of next study.

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