# Study on evaluation of construction reliability for engineering project based on fuzzy language operator

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**Abstract.** System Reliability Theory is a research hotspot of management science and system engineering in recent years, and construction reliability is useful for quantitative evaluation of project management level. According to reliability theory and target system of engineering project management, the defination of construction reliability appears. Based on fuzzy mathematics theory and language operator, value space of construction reliability is divided into seven fuzzy subsets and correspondingly, seven membership function and fuzzy evaluation intervals are got with the operation of language operator, which provides the basis of corresponding method and parameter for the evaluation of construction reliability. This method is proved to be scientific and reasonable for construction condition and an useful attempt for theory and method research of engineering project system reliability.

## 1. Theory system of construction reliability for engineering project

### 1.1. Definition of construction reliability for engineering project

Learning form reliability theory and management ideas, here to define the meaning of the reliability of construction as follows: construction reliability refers to that in the construction process of the project, within the time limit, within the prescribed cost target range, the ability that can achieve the specified engineering quality safely and effectively.

### 1.2. Research content of construction reliability theory system for engineering project

This article mainly involves two aspects:(1)The concept set of the construction reliability for engineering project;(2)Determine the evaluation standards of the construction reliability for engineering project. Namely, the promise is that to   predict scientifically construction reliability of each unit of work and calculate completely the whole system construction reliability, determines evaluation standards for project construction management level ,and evaluates the construction system reliability.

## 2. Dividing the evaluation interval of construction reliability based on fuzzy mathematics theory

### *2.1. Fuzzy language operator and membership function*

Using Fuzzy mathematics to study the evaluation standards of construction reliability for engineering project, the main idea is based on the fuzzy language variables and tone operator of fuzzy mathematics, determines its subordinate function, reasonably divides the evaluation range according to membership function algorithm.

#### *2.1.1.   Fuzzy language variables and operator*

The concept of Language variables in fuzzy mathematics theory is a basic tool of   fuzzy logic and approximate reasoning , it also be known as the high order variable. A language variable has a group of five [5] (x, $U$, $W$ (x), $G$, $M$) denotes

Among them:$X$ is a variable name; $U$ is the domain of discourse;$W$ (x)  (shorthanded as $W$) is the term set of "x", namely, a collection of words or the term of the" x" fuzzy subset name on the "$U$", $x \in W(x)$,also known as the language value of the "x", is a fuzzy variable; $G$ is used to generate the grammar rules of the " x " language value ; $M$ is a semantic rules.

In Natural language, some words such as "briefly", "slightly", "quite", "relatively" and "very", making the degree of words composing in front of a word, for example, the word "good" as the main body forms "better", "very good" [2]etc, it has changed the certain degree of word meaning and made the original word into a new word. Therefore, respectively taking these words as a kind of operator, namely the tone of the operator. Strictly defined as follows:

Set "$X$" as the domain of discourse, to $\lambda \in R^+$,defining map $A \rightarrow H^{(\lambda)}(A), H^{(\lambda)}(A)(x) \triangleq \left(A(x)\right)^{\lambda}$, calls $H^{(\lambda)}$ as tone operator; When the $\lambda > 1$, $H^{(\lambda)}$ calls the centralized operator; When the $\lambda< 1$, $H^{(\lambda)}$ knows as the weakening operator.

set "extremely"=$H^{(4)}$,"very"=$H^{(2)}$, "fair"=$H^{(1.25)}$, "relatively" =$H^{(0.75)}$,"somewhat" = $H^{(0.5)}$ ,"a little"=$H^{(0.25)}$

#### *2.1.2.   Membership function*

Using The fuzzy variables and fuzzy operator to divide evaluation standards of construction reliability for engineering project, and need to determine the reasonable membership function, which is the precondition of   research.

### *2.2. Dividing the evaluation range of construction reliability for engineering project*

#### *2.2.1.   Using fuzzy language operator to define the evaluation range*

On formulating the evaluation standards of construction reliability for engineering project , language variables are the construction reliability, in the domain of course   [0, 1] is within the scope of reliability values, using a tone operator of fuzzy mathematics, it can be divided into seven basic fuzzy subsets, respectively is: very reliable $A_1$, reliable $A_2$, slightly reliable $A_3$, critically reliable $A_4$. slightly unreliable $A_5$, unreliable $A_6$, not very unreliable $A_7$.

#### *2.2.2.   Determine the membership function*

According to the "true" and "false" membership function L.A.Zadeh put forward in 1973 [6], membership function $A_2(x)$ of "reliable" is

$$[reliable](x) = A_2(x) = \begin{cases} 0 & 0 \leq x \leq a \\ 2\left(\dfrac{x-1}{1-a}\right)^2 & a \leq x \leq \dfrac{1+a}{2} \\ 1 - 2\left(\dfrac{x-1}{1-a}\right)^2 & \dfrac{1+a}{2} \leq x \leq 1 \end{cases}$$

Among them: $x = \frac{1+a}{2}$ is known as intersection, $a \in [0,1]$ is a parameter, It says about the subjective judgment of the "x" smallest value.

Membership function of "Not reliable" is that [unreliable] (x) equals to reliable (1-x).

Using $A_1(x)$、$A_2(x)...A_7(x)$ to define respectively the membership function of seven fuzzy subsets, according to the definition of the mentioned fuzzy tone operator, getting the membership function relationship equation between the seven fuzzy subsets. $A_1(x) = [A_2(x)]^2$ ; $A_3(x) = [A_2(x)]^{\frac{1}{2}}$; $A_5(x) = A_3(1-x)$; $A_6(x) = A_2(1-x)$; $A_7(x) = A_1(1-x)$ ; $A_4(x) = A_5(x) \wedge [A_3(x)]^c \wedge [A_5(x)]^c$

These seven basic fuzzy subsets exists the fuzzy contained relationship, there is $A_1 \subseteq A_1 \subseteq A_1$; $A_7 \subseteq A_6 \subseteq A_5$

Through some of the following formula, according to the "dig" way, deducing new seven membership functions, which have not the fuzzy contained relation ,independent of each other   :.   $A_1^*(x) = A_1(x)$  ;  $A_2^*(x) = A_2(x) \wedge A_1(x)$  ;  $A_3^*(x) = A_3(x) \wedge A_2(x)$; $A_4^*(x) = A_4(x)$; $A_5^*(x) = A_3^*(1-x)$; $A_6^*(x) = A_2^*(1-x)$; $A_7^*(x) = A_1^*(1-x)$;

According to the above algorithm, calculating their membership functions , respectively as shown below:

$[very-reliable](x) = A_1^*(x)$

$$= \begin{cases} 0 & 0 \le x \le a \\ 4\left(\dfrac{x-a}{1-a}\right)^4 & a \le x \le \dfrac{1+a}{2} \\ \left[1 - 2\left(\dfrac{x-1}{1-a}\right)^2\right]^2 & \dfrac{1+a}{2} \le x \le 1 \end{cases}$$

$[very-unreliable](x) = A_7^*(x)$

$$= \begin{cases} \left[1 - 2\left(\dfrac{x}{1-a}\right)^2\right]^2 & 0 \le x \le 0.5(1-a) \\ 4\left(\dfrac{1-x-a}{1-a}\right)^4 & 0.5(1-a) \le x \le 1-a \\ 0 & 1-a \le x \le 1 \end{cases}$$

$[critically-reliable](x) = A_4^*(x) = \begin{cases} 1 - \sqrt{2}\left(\dfrac{x}{1-a}\right) & 0 \le x \le \dfrac{1-a}{2} \\ 1 - \sqrt{2}\left(\dfrac{1-x-a}{1-a}\right) & \dfrac{1-a}{2} \le x \le 1-a \\ 1 & 1-a \le x \le a \\ 1 - \sqrt{2}\left(\dfrac{x-a}{1-a}\right) & a \le x \le \dfrac{1+a}{2} \\ 1 - \sqrt{2}\left(\dfrac{1-x}{1-a}\right) & \dfrac{1+a}{2} \le x \le 1 \end{cases}$

$[reliable](x) = A_2^*(x)$

$$= \begin{cases} 0 \\ 2\left(\dfrac{x-a}{1-a}\right)^4 & 0 \le x \le a \\ 1 - 2\left(\dfrac{x-1}{1-a}\right)^2 & a \le x \le \dfrac{1+a}{2} \\ \left[1 - 2\left(\dfrac{x-1}{1-a}\right)^2\right]^2 & \dfrac{1+a}{2} \le x \le 1-0.437(1-a) \\ & 1-0.437(1-a) \le x \le 1 \end{cases}$$

$[slightly-unreliable](x) = A_5^*(x)$

$$= \begin{cases} 2\left(\dfrac{x-1}{1-a}\right)^2 & 0 \le x \le \dfrac{1-a}{2} \\ 1 - 2\left(\dfrac{1-x-a}{1-a}\right)^2 & \dfrac{1-a}{2} \le x \le 0.563(1-a) \\ \sqrt{2}\left(\dfrac{1-x-a}{1-a}\right) & 0.563(1-a) \le x \le 1-a \\ 0 & 1-a \le x \le 1 \end{cases}$$

$[slightly-reliable](x) = A_3^*(x)$

$$= \begin{cases} 0 & 0 \le x \le a \\ \sqrt{2}\left(\dfrac{x-a}{1-a}\right) & a \le x \le a+0.437(1-a) \\ 1 - 2\left(\dfrac{x-1}{1-a}\right)^2 & a+0.437(1-a) \le x \le \dfrac{1+a}{2} \\ 2\left(\dfrac{x-1}{1-a}\right)^2 & \dfrac{1+a}{2} \le x \le 1 \end{cases}$$

$[unreliable](x) = A_6^*(x)$

$$= \begin{cases} 1 - \left[1 - 2\left(\dfrac{x}{1-a}\right)^2\right]^2 & 0 \le x \le 0.437(1-a) \\ 1 - 2\left(\dfrac{x}{1-a}\right)^2 & 0.437(1-a) \le x \le \dfrac{1-a}{2} \\ 2\left(\dfrac{1-x-a}{1-a}\right)^2 & \dfrac{1-a}{2} \le x \le 1-a \\ 0 & 1-a \le x \le 1 \end{cases}$$

*2.2.3.  The solution of evaluation range*

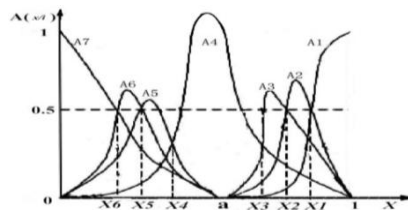According to the above seven subordinate functions obtained, drawing the graph, as shown in figure 1.

**Fig.1** Membership function curve and intersections

From figure 1, the value space of the reliability[0, 1] was divided six intersections of seven function curve into seven independent evaluation range, using the principle of maximum membership degree to judge the fuzzy language values of the corresponding intervals .

The corresponding reliability value of each node is calculated respectively, the result is $X_1 = 0.617 + 0.383a$ , $X_2 = \frac{1+a}{2}$ , $X_3 = 0.354 + 0.646a$ , $X_4 = 0.646(1-a)$ , $X_5 = 0.5(1-a)$ , $X_6 = 0.383(1-a)$

The probability interval $[X_1, 1]$ corresponds to language value  "very reliable", $[X_2, X_1]$ corresponds to the "reliable", $[X_3, X_2]$ corresponds to the "slightly reliable", $[X_4, X_3]$ corresponds to the "critically reliable ", $[X_5, X_4]$ corresponds to the "slightly unreliable", $[X_6, X_5]$ corresponds to the "unreliable", $[0, X_6]$ corresponds to the "very unreliable".

*2.2.4.   the determination of parameters "a" in evaluation range*

From the above analysis results can be seen, values of the parameters "a" in the membership function directly impacts the division of assessment interval. "a" value changes because of the difference of distinguishing engineering project in different regions or types, which reflects principle of distinction and   dynamism of evaluation criterion. In a practical application, choosing the typical engineering and statistically analyzing the historical data ,reasonably valuing the membership function and parameters "a". this is the key to determine reasonably the evaluation interval of construction reliability.

Assume that parameters "a" equals to 0.6, each evaluation interval as shown in table 1.

**Tab.1** Evaluation interval of construction reliability for engineering project

| Fuzzy language | interval | Fuzzy language | interval |
|---|---|---|---|
| Very reliable | [0.847，1] | Slightly | [0.200，0.258] |
| reliable | [0.800,0.847] | unreliable | [0.153，0.200] |
| slightly reliable | [0.742,0.800] | very unreliable | [0，0.153] |
| critically | [0.258,0.742] | | |

## 3.   Conclusion

Based on the System Reliability Theory, we introduce construction reliability in engineering project management to carry out exploratory research for construction reliability and evaluation standards of engineering project. Main conclusions are as follows: (1)Define the concept of construction reliability for engineering project , its meaning refers to the period credibility, cost economy, quality accessibility and construction safety. (2)Reasonably divide the evaluation range of construction reliability based on fuzzy language operator of fuzzy mathematics theory. Reliability value space can be divided into seven fuzzy subsets, such as "very reliable", "reliable", "slightly reliable", "critically reliable", "slightly unreliable", "unreliable", "very unreliable", obtaining the membership function of fuzzy subset according to the relationship between mood operator, the value space of the reliability[0, 1] was divided to six intersections of seven function curves into seven independent evaluation ranges, using the principle of maximum membership degree to judge the fuzzy language values of the corresponding intervals . The division of the evaluation interval according to membership function is affected by the parameters "a" of the membership function ."a" value changes because of the difference of distinguishing engineering project in different regions or types, which reflects principle of distinction and dynamism of evaluation criterion.

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