Construction Project Risk Factors Ranking based on Uncertain Linguistic Variable

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Abstract: According to linguistic description in construction project risk factors ranking problem, uncertain linguistic variable is used to quantify these natural language. The construction project risk factors ranking model is proposed based on uncertain linguistic variable and C-OWA operator to predict main risk factors. Finally, an illustrative example shows the feasibility of the proposed method.

Keywords: Construction project, risk factors ranking , uncertain linguistic variable, C-OWA operator

1. Introduction

Construction project risk factors ranking that is one of key tasks of risk identification can find main risk factors and provide theoretical basis for taking pre-control measures. However, it is difficult to collect enough similar projects data because of the one-time nature of construction project and the complexity and uncertainty of construction process. It often depends on experts' evaluation information to rank construction project risk factors. Experts are used to use natural language to give evaluation information because of the limitation of their subjective judgment and the fuzziness of their thinking. It makes construction project risk information reflect some linguistic description feature.

In recent years, studies on quantifying natural language have achieved some results. Among these results, uncertain linguistic variable can not only quantify natural language, but also take advantage of interval number to allow parameter values to change within a certain range. It is more in line with actual information expression habit. Thus, uncertain linguistic variable is used to express construction project risk information. The construction project risk factors ranking model is developed based on uncertain linguistic variable and C-OWA operator to predict main risk factors.

2. Uncertain Linguistic Variable

Definition 1[1]. If suppose $F_{\rho([a,b])}$ is the C-OWA operator of closed interval number $[a,b]$, Its expression is defined as:

$$F_{\rho([a,b])}=\int_0^1 \frac{d\rho(y)}{dy}\big(b-y(b-a)\big)dy \tag{1}$$

Where $\rho:[0,1]\to[0,1]$, $\rho(0)=0$, $\rho(1)=1$ and ρ is a basic unit interval monotone function, i.e. $y>z\Rightarrow\rho(y)>\rho(z)$. If suppose $\rho(y)=y^{\theta}\,(\theta\ge 0)$, its expression is defined as:

$$F_{\rho([a,b])}=\frac{b+\theta a}{\theta+1} \tag{2}$$

Definition 2[2-3]. Suppose that $H=\left[H_0,H_1,H_2,\cdots,H_{(f-2)},H_{(f-1)}\right]$ is a discrete, finite and totally ordered linguistic evaluation set, where f is the odd value. In real situation, f is equal to 3, 5, 7, 9 etc. The relationship between any element H_h in H and its subscript h is the strictly monotone increasing. To preserve all the given information, H is extended to a continuous linguistic evaluation set $H'=\{H_h | h\in R\}$, which satisfies the above characteristics. Suppose $H_{\underline{h(x_i)}},H_{\overline{h(x_i)}}\in H'$ and $\underline{h(x_i)}\le\overline{h(x_i)}$, then let $H_{h(x_i)}=\left[H_{\underline{h(x_i)}},H_{\overline{h(x_i)}}\right]$ be called an uncertain linguistic variable. It is interpreted as the linguistic evaluation word of x_i is $\left[H_{\underline{h(x_i)}},H_{\overline{h(x_i)}}\right]$. U is a given domain, $U=[x_i], i=1,2,\cdots,n$, λ_i is a positive real number. There are the following operation rules.

$$H_{h(x_1)}+H_{h(x_2)}=\left[H_{\underline{h(x_1)}+\underline{h(x_2)}},H_{\overline{h(x_1)}+\overline{h(x_2)}}\right] \tag{3}$$

$$\lambda_i H_{h(x_i)}=\left[H_{\lambda_i \underline{h(x_i)}},H_{\lambda_i \overline{h(x_i)}}\right] \tag{4}$$

$$\sum_{i=1}^{n}\left(\lambda_i H_{h(x_i)}\right)=\left[H_{\sum_{i=1}^{n}\left(\lambda_i \underline{h(x_i)}\right)},H_{\sum_{i=1}^{n}\left(\lambda_i \overline{h(x_i)}\right)}\right] \tag{5}$$

3. Model

Use uncertain linguistic variable and C-OWA operator to develop construction project risk factors ranking model to predict main risk factors.

3.1. Parameters

Suppose D is an evaluation objective. C is an evaluation criteria set, and there is $C=[C_c], c=1,2,\cdots,m$. U is an evaluation index set, and there is $U=[x_i], i=1,2,\cdots,n$. S is an expert set, and there is $S=[S_s], s=1,2,\cdots,k$. δ is an expert weight vector and there are $\delta=[\delta_s]_{1\times k}=[\delta_1,\delta_2,\cdots,\delta_k]$, $\sum_{s=1}^{k}\delta_s=1$ and $\delta_s \ge 0$. γ is a criteria weight vector and there are $\gamma=[\gamma_c]_{1\times m}=[\gamma_1,\gamma_2,\cdots,\gamma_m]$, $\sum_{c=1}^{m}\gamma_c=1$ and $\gamma_c \ge 0$. $H_{h_{ics}}=\left[H_{\underline{h_{ics}}},H_{\overline{h_{ics}}}\right]$ is an uncertain linguistic variable that expert S_s estimates the linguistic evaluation word of index x_i on criteria C_c .

3.2. Model

Step 1. $H_{h_{ics}}$ are expert-weighted by formula (5) to get experts' uncertain linguistic variable. Its expression is as follows.

$$H_{h_{ic}}=\left[H_{\underline{h_{ic}}},H_{\overline{h_{ic}}}\right]=\left[H_{\sum_{s=1}^{k}\left(\delta_s \underline{h_{ics}}\right)},H_{\sum_{s=1}^{k}\left(\delta_s \overline{h_{ics}}\right)}\right] \quad (6)$$

Step 2.Use formula (1) to calculate the aggregation value of $H_{h_{ic}}$. Its expression is as follows.

$$F_{\rho\left(H_{h_{ic}}\right)}=\int_0^1 \frac{d\rho(y)}{dy}\left(\overline{h_{ic}}-y\left(\overline{h_{ic}}-\underline{h_{ic}}\right)\right)dy \quad (7)$$

Suppose $\rho(y)=y^{\theta}(\theta \ge 0)$, use formula (2) to calculate the aggregation value of $H_{h_{ic}}$. Its expression is as follows.

$$F_{\rho\left(H_{h_{ic}}\right)}=\frac{\overline{h_{ic}}+\theta \underline{h_{ic}}}{\theta+1} \quad (8)$$

Step 3. $F_{\rho\left(H_{h_{ic}}\right)}$ are criteria-weighted to get ranking values. Its expression is as follows.

$$E_i=\sum_{c=1}^{m}\left(\gamma_c F_{\rho\left(H_{h_{ic}}\right)}\right) \quad (9)$$

Step 4. Suppose E_1 and E_2 are the ranking values of x_1 and x_2 , the ranking rules is as follows.

$$E_1 > E_2 \Rightarrow x_1 > x_2 \quad (10)$$

Where if $E_1 > E_2$, the influence of x_1 is greater than the influence of x_2 .

4. Illustrative Example

There is a construction project called XXX. Take XXX construction project risk as evaluation target. Take basic construction project management objectives as evaluation criterion. Take risk factors as evaluation indexes. The risk analysis hierarchy structure is constructed (Figure 1). $H=[H_0,H_1,H_2,H_3,H_4]$ is an linguistic evaluation set, where H_0 is the smallest risk status. H_1 is the smaller risk status. H_2 is the moderate risk status. H_3 is the bigger risk status, H_4 is the biggest risk status. $S=[S_1,S_2,S_3,S_4,S_5]$ is an expert set. Invite them to estimate uncertain linguistic number $H_{h_{ics}}=\left[H_{\underline{h_{ics}}},H_{\overline{h_{ics}}}\right]$ of the influence of each index on each criteria according figure 1. Build decision table (Table 1). Expert weights are known, i.e. $\delta=[0.1494,0.2249,0.2505,0.1753,0.1999]$. Criteria weights are known, i.e. $\gamma=[0.2126,0.1991,0.2497,0.2673,0.0713]$. Please predict main risk factors.

Table 1. Decision Table of Uncertain Linguistic Variable.

x_i	$H_{h_{i11}}$	$H_{h_{i21}}$	$H_{h_{i31}}$	$H_{h_{i41}}$	$H_{h_{i51}}$	$H_{h_{i12}}$	$H_{h_{i22}}$	$H_{h_{i32}}$	$H_{h_{i42}}$	$H_{h_{i52}}$	$H_{h_{i13}}$	$H_{h_{i23}}$	$H_{h_{i33}}$	$H_{h_{i43}}$	$H_{h_{i53}}$	$H_{h_{i14}}$	$H_{h_{i24}}$	$H_{h_{i34}}$	$H_{h_{i44}}$	$H_{h_{i54}}$	$H_{h_{i15}}$	$H_{h_{i25}}$	$H_{h_{i35}}$	$H_{h_{i45}}$	$H_{h_{i55}}$
x_1	[3,4]	[3,3]	[4,4]	[4,4]	[0,1]	[3,4]	[3,4]	[4,4]	[4,4]	[2,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[3,4]	[3,4]	[4,4]	[4,4]	[2,3]	[3,4]	[3,3]	[4,4]	[4,4]	[2,3]
x_2	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[3,4]	[4,4]	[4,4]	[3,4]	[2,3]	[4,4]	[4,4]	[4,4]	[3,4]	[2,3]
x_3	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]	[4,4]	[3,4]	[3,4]	[3,4]	[3,3]	[4,4]	[4,4]	[4,4]	[4,4]	[2,3]
x_4	[2,3]	[2,3]	[3,4]	[4,4]	[0,1]	[2,3]	[1,2]	[4,4]	[3,4]	[0,1]	[2,3]	[2,3]	[3,4]	[3,4]	[0,1]	[2,3]	[2,3]	[4,4]	[3,4]	[0,1]	[3,4]	[3,4]	[3,4]	[3,4]	[0,1]
x_5	[2,3]	[3,3]	[2,3]	[3,4]	[0,1]	[3,3]	[2,3]	[3,4]	[3,4]	[0,1]	[2,3]	[2,3]	[3,3]	[3,4]	[0,1]	[3,3]	[3,3]	[2,3]	[3,4]	[0,1]	[3,3]	[3,3]	[3,4]	[3,4]	[0,1]
x_6	[0,1]	[0,1]	[4,4]	[3,4]	[0,1]	[0,1]	[0,1]	[4,4]	[3,4]	[0,1]	[0,1]	[0,1]	[4,4]	[3,3]	[0,1]	[0,1]	[0,1]	[4,4]	[3,4]	[0,1]	[0,1]	[0,1]	[4,4]	[3,3]	[0,1]
x_7	[2,3]	[3,3]	[2,3]	[4,4]	[1,2]	[2,3]	[3,3]	[3,3]	[3,4]	[0,1]	[3,3]	[2,3]	[3,3]	[4,4]	[0,1]	[3,3]	[3,3]	[2,3]	[4,4]	[0,1]	[3,3]	[2,3]	[2,3]	[3,4]	[0,1]
x_8	[2,3]	[2,3]	[2,3]	[2,3]	[2,3]	[1,2]	[2,2]	[2,3]	[2,3]	[2,3]	[2,3]	[2,3]	[3,3]	[3,3]	[3,3]	[2,3]	[2,3]	[3,3]	[3,3]	[2,3]	[2,3]	[2,3]	[2,3]	[3,3]	[2,3]
x_9	[4,4]	[3,3]	[3,4]	[4,4]	[2,3]	[4,4]	[3,4]	[3,4]	[4,4]	[2,3]	[4,4]	[3,3]	[4,4]	[4,4]	[2,3]	[4,4]	[3,4]	[3,4]	[4,4]	[2,3]	[4,4]	[3,4]	[4,4]	[4,4]	[3,4]

Risk factors ranking process is as follows.

Step 1 Use formula (6) to calculate experts' uncertain linguistic variable.

Step 2 θ in formula (8) is known, i.e. θ=2 [4]. Use formula (8) to calculate the aggregation value of the uncertain linguistic variable

Step 3 Use formula (9) to calculate ranking values (Figure 2).

Step 4 Use formula (10) to rank risk factors. The ranking result shows that "construction risk" > "design risk" > "force majeure risk" > "early decision-making errors risk" > "contract risk" > "resource supply risk" > "organization risk" > "politics and law risk" > "market risk".

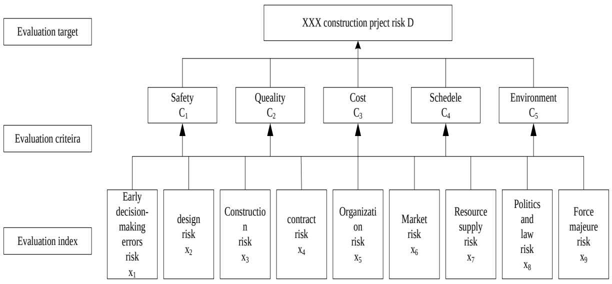

Figure 1. Risk Analysis Hierarchical Structure of XXX Construction Project.

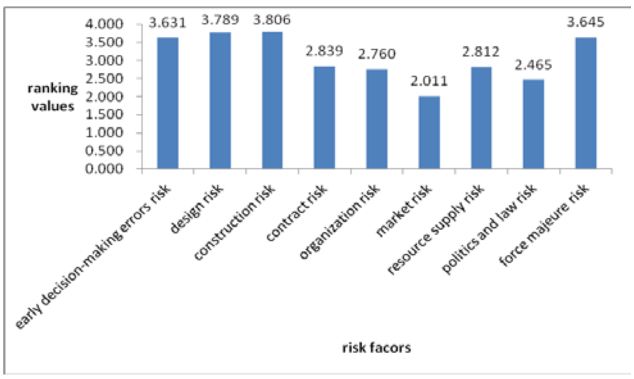

Figure 2. Calculating Results.

5. Conclusion

The theoretical prediction result calculated by the developed model is in line with actual construction project situation. Therefore, it is feasible to use uncertain linguistic variable and C-OWA operator to develop construction project risk factors ranking model to predict main risk factors.

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