

The Risk Assessment Research of Construction Engineering Project under Fuzzy Environment Based on TOPSIS

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Abstract

The paper presents risk assessment of construction objects under the fuzzy environment based on multi-attribute decision making method of TOPSIS. Firstly, while the risk factors of construction engineering project are analyzed, the risk criteria set is established clearly. Then the TOPSIS method is applied to assess the risk of project with fuzzy information, and the ranking of the alternatives can be obtained according to the assessment results. Lastly the example illustrates the detailed application process of fuzzy TOPSIS, and verifies the effectiveness and feasibility of the proposed risk criteria set and TOPSIS method, and shows that the research has some practical and scientific value.

Keywords

Multi-Attribute Decision Making, Fuzzy TOPSIS, Construction Project, Risk Assessment

基于TOPSIS的模糊环境下建筑工程项目风险评估研究

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摘要

基于多属性决策TOPSIS方法对模糊环境下建筑工程项目的风险评估问题进行研究。首先对建筑工程项目的风险因素进行分析，构建建筑项目风险属性集，并给出各因素的权重。然后应用TOPSIS方法对模糊环境下的项目风险进行评估，并对备选项目进行排序。案例详细说明了相关方法的具体应用过程，验证了风险属性集和方法的有效性和实用性，对建筑工程项目的风险管理具有一定的实践和理论价值。

关键词

多属性决策，模糊TOPSIS，建筑项目，风险评估

1. 引言

现代建筑工程项目的内外环境处在动态的变化中，出现的问题更加复杂，许多相互关联的因素导致项目伴随着高不确定性和风险。与其他工业相比，建筑行业因为自身的特殊性，相关的工程项目会更具风险性，例如周期长、过程复杂，糟糕的外部环境，财务紧张，组织结构动态变化等。由于建筑项目风险造成的损失是触目惊心的，因此在现代建筑项目管理中，风险管理问题已成为研究的热点之一。目前国内关于建筑工程项目的研究多集中在建筑教育教学[1]、项目管理[2] [3]、先进技术和观念引入[4]等方面，对项目风险的相关研究尚不深入。本文在信息模糊条件下对建筑工程项目备选方案及其全部风险进行评估，基于对建筑项目风险的分析，构建项目风险评估属性集，并基于逼近理想解的排序方法(Technique for Order Preference by Similarity to Ideal Solution, TOPSIS) [5]对模糊环境下的项目风险进行评估，并对备选项目进行有限排序。

2. 建筑工程项目风险分析

2.1. 风险因素分析

不同的土木建筑工程项目其开发、涉及技术及管理条件也会有所区别，即不同的土木建筑、项目和公司面临着一般会面临着不同层次的风险，一般可概括为国家，工业，项目和企业等层次。且由于土木建筑项目涉及到业主、设计方、承包商、转包商、供应商等多个合同缔约方，组成复杂，具有许多受制于经济、政治、社会、文化等条件的固有风险。作为一种不确定事件或状况，项目风险会对整个项目的目标(时间、费用、安全、质量等)产生正面或负面的影响。项目风险源一般可以分为承包商、顾问和客户等，为便于分析，本文细化整理了项目风险的可能影响因素，形成建筑工程项目风险评估的属性集，主要元素包括：对国内经济状况(C1)、项目特异性(C2)、国际环境动态(C3)、公司特异性(C4)、劳动力(C5)、总承包(C6)、咨询服务(C7)、合同管理(C8)、转包(C9)、设计 - 施工(C10)、机遇分析(C11)、合同条款(C12)、

建设(C13)、可行性研究(C14)、设计(C15)、运营(C16)、预约(C17)、采购(C18)、后评估(C19)等, 其中后评估是指项目建设投产后, 对建设项目进行后评估, 如图 1 所示。

2.2. 风险属性权重计算

三角模糊数[6]一般表示为一个三元组 (a,b,c) , 其中 a, b, c 为实数, 那么三角模糊变量 $M = (a,b,c)$ 的隶属函数为

$$\mu(x) = \begin{cases} \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{x-b}{c-b}, & b \leq x \leq c \\ 0, & \text{其他} \end{cases} \quad (1)$$

那么两个模糊数 $M_1 = (a_1, b_1, c_1)$ 和 $M_2 = (a_2, b_2, c_2)$ 之间的距离为

$$d(M_1, M_2) = \sqrt{\frac{1}{3} [(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \quad (2)$$



Figure 1. The attribute weights of risk in construction project
图 1. 建筑工程项目风险属性权重

由于人类思维的模糊性，在处理复杂或无法准确描述问题时，人们一般喜欢用“小”、“好”、“差”等语义型变量来进行判断和描述，为了表示这些模糊概念，文献[6]-[9]中给出了 0~1 标度、0.1~0.9 标度、1~9 标度等的模糊数表示形式，本文采用 1~9 标度，属性重要度的语言变量与模糊数对应情况如表 1 所示。

利用模糊 AHP 法对风险属性权重进行计算，得到结果如图 1 所示。

3. 模糊环境下基于 TOPSIS 的项目风险评估

假设有建筑工程项目方案集 $P = (P_j, j = 1, \dots, n)$ ，项目评估属性集为 $C = (C_i, i = 1, \dots, m)$ ，此处 $m = 19$ 。用三角模糊数 $M_{ij} = (a_{ij}, b_{ij}, c_{ij})$ 表示方案 P_j 在属性 C_i 下的评价值，那么可形成决策矩阵 $A = (M_{ij})_{m \times n}$ 。

TOPSIS 法将方案集中同时距理想解最近，且距负理想解最远的方案作为问题解。本文利用 TOPSIS 法思想，给出建筑工程项目方案风险评估的算法步骤：

Step 1: 形成初始决策矩阵 $A = (M_{ij})_{m \times n}$ ，其中 m 为风险属性数量， n 为项目方案数量。

Step 2: 对初始决策矩阵 $A_{m \times n}$ 进行规范化[10]，得到规范化决策矩阵 $X = (x_{ij})_{m \times n}$ ，具体方法如下。

$$x_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), x_{ij} \text{ 为效益型值}, x_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), x_{ij} \text{ 为损失型值} \quad (3)$$

其中 $c_i^* = \max_j c_{ij}$ ， $a_i^- = \min_j a_{ij}$ ， $i = 1, \dots, m$ ； $j = 1, \dots, n$ 。

Step 3: 根据文献[10]中关于运算“ \otimes ”的定义，计算规范化加权评估值 $H_{ij} = w_i \otimes x_{ij}$ ， $i = 1, \dots, m$ ； $j = 1, \dots, n$ 。

Step 4: 确定正理想解 OP^+ 和负理想解 OP^- ，方法如下。

$$OP^+ = \{h_1^+, \dots, h_m^+\} = \left\{ \max_j H_{ij}, i = 1, \dots, m \right\} \quad (4)$$

$$OP^- = \{h_1^-, \dots, h_m^-\} = \left\{ \min_j H_{ij}, i = 1, \dots, m \right\} \quad (5)$$

Step 5: 计算各方案分别与理想解和负理想解的距离 d_j^+ 和 d_j^- 。

$$d_j^+ = \sum_{i=1}^m d(H_{ij}, OP_i^+) \quad (6)$$

$$d_j^- = \sum_{i=1}^m d(H_{ij}, OP_i^-) \quad (7)$$

Step 6: 计算各方案与模糊理想解的贴近系数 β_j 。

$$\beta_j = \frac{d_j^-}{d_j^- + d_j^+} \quad (8)$$

贴近系数 β_j 越大，说明方案更靠近正理想解，远离负理想解。用贴近系数可以完成对各方案优劣的排序。

4. 案例分析

现有三个建筑工程项目 (P_1, P_2, P_3) ，需对各项目进行风险评估，从中选择风险最小的方案进行实施。三个方案在设计、结构、建筑技术、面积、楼层、位置等各有不同，初始的决策矩阵如表 2 所示，表示各方案在各风险属性上的表现。

根据上文所述的建筑工程项目方案风险评估的算法步骤，首先对初始决策矩阵进行标准化得到规范化决策矩阵 X ，并根据算法步骤 3 计算规范化加权评估值，可得到 H

Table 1. Fuzzy quantization scale of attribute significance
表 1. 属性重要度的模糊量化标度

语言定义	小(差)	较小(较差)	中等	很高(很好)	极高(极好)	属性类型
数值等级	(1,1,2)	(2,3,4)	(4,5,6)	(6,7,8)	(8,9,9)	效益型
	(9,9,8)	(8,7,6)	(6,5,4)	(4,3,2)	(2,1,1)	损失型

Table 2. The initial fuzzy assessment of each program in each attribute
表 2. 各方案在各属性下的初始评估模糊值

属性	P_1	P_2	P_3	属性	P_1	P_2	P_3
C1	(4,5,6)	(4,5,6)	(2,3,4)	C11	(4,5,6)	(1,2,3)	(3,4,5)
C2	(4,5,6)	(3,4,5)	(1,2,3)	C12	(3,4,5)	(1,2,3)	(1,1,2)
C3	(3,4,5)	(1,2,3)	(2,3,4)	C13	(4,5,6)	(3,4,5)	(2,3,4)
C4	(2,3,4)	(1,1,2)	(3,4,5)	C14	(3,4,5)	(2,3,4)	(1,2,3)
C5	(2,3,4)	(1,2,3)	(3,4,5)	C15	(4,5,6)	(3,4,5)	(2,3,4)
C6	(3,4,5)	(1,2,3)	(1,1,2)	C16	(3,4,5)	(3,4,5)	(1,2,3)
C7	(2,3,4)	(1,2,3)	(1,1,2)	C17	(1,2,3)	(2,3,4)	(3,4,5)
C8	(3,4,5)	(1,2,3)	(1,2,3)	C18	(2,3,4)	(1,2,3)	(2,3,4)
C9	(3,4,5)	(1,2,3)	(2,3,4)	C19	(2,3,4)	(1,1,2)	(1,1,2)
C10	(4,5,5)	(1,2,3)	(1,2,3)				

$$H = \begin{bmatrix} (0.0293,0.0542,0.0890) & (0.0293,0.0542,0.0890) & (0.0176,0.0390,0.0712) \\ (0.0200,0.0467,0.0890) & (0.0150,0.0373,0.0742) & (0.0060,0.0224,0.0534) \\ (0.0220,0.0433,0.0742) & (0.0073,0.0217,0.0445) & (0.0176,0.0390,0.0712) \\ (0.0050,0.0170,0.0393) & (0.0025,0.0057,0.0197) & (0.0090,0.0272,0.0590) \\ (0.0050,0.0170,0.0393) & (0.0025,0.0113,0.0295) & (0.0090,0.0272,0.0590) \\ (0.0075,0.0267,0.0617) & (0.0025,0.0133,0.0370) & (0.0030,0.0080,0.0296) \\ (0.0147,0.0290,0.0493) & (0.0073,0.0193,0.0370) & (0.0088,0.0116,0.0296) \\ (0.0220,0.0387,0.0617) & (0.0073,0.0193,0.0370) & (0.0088,0.0232,0.0444) \\ (0.0220,0.0433,0.0742) & (0.0073,0.0217,0.0445) & (0.0176,0.0390,0.0712) \\ (0.0293,0.0542,0.0742) & (0.0073,0.0217,0.0445) & (0.0088,0.0260,0.0534) \\ (0.0293,0.0542,0.0890) & (0.0073,0.0217,0.0445) & (0.0264,0.0520,0.0890) \\ (0.0220,0.0433,0.0742) & (0.0073,0.0217,0.0445) & (0.0088,0.0130,0.0356) \\ (0.0293,0.0542,0.0890) & (0.0220,0.0433,0.0742) & (0.0176,0.0390,0.0712) \\ (0.0075,0.0227,0.0492) & (0.0050,0.0170,0.0393) & (0.0030,0.0136,0.0354) \\ (0.0100,0.0283,0.0590) & (0.0075,0.0227,0.0492) & (0.0060,0.0204,0.0472) \\ (0.0220,0.0387,0.0617) & (0.0220,0.0387,0.0617) & (0.0088,0.0232,0.0444) \\ (0.0073,0.0217,0.0445) & (0.0147,0.0325,0.0593) & (0.0264,0.0520,0.0890) \\ (0.0050,0.0170,0.0393) & (0.0025,0.0113,0.0295) & (0.0060,0.0204,0.0472) \\ (0.0050,0.0200,0.0493) & (0.0025,0.0067,0.0247) & (0.0030,0.0080,0.0296) \end{bmatrix}$$

根据步骤 4 确定正理想解和负理想解分别为

	OP^+	OP^-
C_1	(0.0293,0.0542,0.0890)	(0.0176,0.0390,0.0712)
C_2	(0.0200,0.0467,0.0890)	(0.0060,0.0224,0.0534)
C_3	(0.0220,0.0433,0.0742)	(0.0073,0.0217,0.0445)
C_4	(0.0090,0.0272,0.0590)	(0.0025,0.0057,0.0197)
C_5	(0.0090,0.0272,0.0590)	(0.0025,0.0113,0.0295)
C_6	(0.0075,0.0267,0.0617)	(0.0025,0.0080,0.0296)
C_7	(0.0147,0.0290,0.0493)	(0.0073,0.0116,0.0296)
C_8	(0.0220,0.0387,0.0617)	(0.0073,0.0193,0.0370)
C_9	(0.0220,0.0433,0.0742)	(0.0073,0.0217,0.0445)
C_{10}	(0.0293,0.0542,0.0742)	(0.0073,0.0217,0.0445)
C_{11}	(0.0293,0.0542,0.0890)	(0.0073,0.0217,0.0445)
C_{12}	(0.0220,0.0433,0.0742)	(0.0073,0.0130,0.0356)
C_{13}	(0.0293,0.0542,0.0890)	(0.0176,0.0390,0.0712)
C_{14}	(0.0075,0.0227,0.0492)	(0.0030,0.0136,0.0354)
C_{15}	(0.0100,0.0283,0.0590)	(0.0060,0.0204,0.0472)
C_{16}	(0.0220,0.0387,0.0617)	(0.0088,0.0232,0.0444)
C_{17}	(0.0264,0.0520,0.0890)	(0.0073,0.0217,0.0445)
C_{18}	(0.0060,0.0204,0.0472)	(0.0025,0.0113,0.0295)
C_{19}	(0.0050,0.0200,0.0493)	(0.0025,0.0067,0.0247)

根据步骤 5 分别计算各方案与正、负理想解的距离，可求出三个建筑工程项目与正理想解的距离分别为 $d_1^+ = 0.0640$ ， $d_2^+ = 0.3083$ ， $d_3^+ = 0.2189$ ；与负理想解的距离分别为 $d_1^- = 0.3283$ ， $d_2^- = 0.0853$ ， $d_3^- = 0.1777$ 。那么利用式(8)可计算得到各项目的贴近系数为 $\beta_1 = 0.8369$ ， $\beta_2 = 0.2167$ ， $\beta_3 = 0.4481$ ，即综合上看，项目 P_1 在各风险属性上表现较好，风险最小；项目 P_2 在各风险属性上表现较差，风险最大，项目的排序情况为 $P_2 < P_3 < P_1$ 。

5. 结论

风险评估则是项目风险管理重要内容之一，本文全面地考虑了建筑工程项目中可能存在的 19 个风险因素，构建了建筑工程项目风险评估的风险属性集，并给出其模糊权重。利用模糊 TOPSIS 法对建筑工程项目的风险情况进行综合评估，并给出了具体算法步骤。通过案例证明了文中提出的风险属性集和评估方法的有效性和实用性，对建筑工程项目的风险管理和建设具有一定的实践和理论价值。

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