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A Decision Support System for Construction Project Risk Assessment

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Abstract

This paper presents an integrated system in which a computer-based decision support system (DSS) for construction project risks assessment at stage of contracting and construction. The Analytic Hierarchy Process (AHP) method is used to determine the weightings of risk factors from subjective judgment of experts and practitioners, and Fuzzy Multiple Criteria Decision Making (FMCDM) is used to assess the synthetic judgment of risk degree for the main activities of a construction project in different phase. A simple case study illustrates the effectiveness of the proposed approach and developed system.

1.Introduction

Construction is one of the most dynamic, risky, challenging, and rewarding industrial sectors [16]. Accordingly, construction activities are uncertain and variable, and associated risks are often permanent and complex in construction projects. Especially, large-scale construction projects (such as high-rise commercial building projects and mass transit system projects, and mountain tunnel construction projects) are becoming increasingly complex and variable in nature, and many risk and uncertainty factors are inherent. However, the construction industry often has a poor reputation for dealing with risk and uncertainty adequately, resulting in poor performance with failure to meet schedule deadlines and budgets, and attendant loss to both contractors and owners [15] [27]. In this case, effective risk and uncertainty management is a form of incentive to the contractors, as their profit margin will often be secured or even improved. This is particularly significant as projects including large capital outlays, unbalanced cash flows, significant new technology, unusual legal or contractual arrangements and sensitive environmental or safety issues [5]. However, construction risk and uncertainty can seldom, if ever, be eliminated. A comprehensive risk and uncertainty analysis is not necessary to prevent cost and schedule overruns but, at least, it will give those parties a more rational basis on which to make decision.

A number of analysis model reported in the literature that provide management knowledge on the risk and uncertainty inherent in a project and lead to better decision outcomes. These risk handle methods can be considered to fall into three categories: (1) probability analysis [11] [13] [28] [31]; (2) interval analysis [2] [7] [18]; and (3) fuzzy set analysis [15] [20] [25] [26]. Probabilistic analysis techniques include sensitivity analysis, basic probability analysis, decision-tree analysis, Monte Carlo simulation. However, some of literature studies and surveys reported indicate that probability risk analysis is not widely accepted [1]. Interval analysis uses ranges for input variables to estimate plausible ranges of the results. However, it is difficult to define the intervals of input variables when the boundaries of the intervals are uncertain. A fuzzy set approach, pioneered by Zadeh [32], is a means for modeling uncertainty (or imprecision) arising from mental phenomena, which are neither random nor stochastic [9]. It is useful for uncertainty analysis where a probabilistic data is not available or when interval values of input variables are uncertain. Thus, this study attempts to apply the Analytic Hierarchy Process (AHP) to determine the impact weights of risk factors from subjective judgment of experts and practitioners. Further, the Fuzzy Multiple Criteria Decision Making (FMCDM) was used to assess the synthetic judgment of degree of risk for the main activities of a construction project in different phase. On the other hand, due to advances in computer technologies and current information exchange capabilities, there exists a need to develop a decision support system (DSS) that will assist the contractors in making critical risk management decisions at the stages of contracting and construction. Thus, the aim of this paper is to present a systemic approach of the implementation of DSS in risk assessment of construction project. Initially, the establishment of a hierarchical structure for tackling the problem of construction risk and uncertainty identification is discussed, and a brief introduction to FMCDM methods. Then, introduce the DSS framework that we developed. Finally, concluding remarks are presented.

2.Construction Project Risk Assessment Model

The purpose of this section is to establish a hierarchical structure for tackling the problem of risk assessment of a construction project. The contents include three subsections: constructing the hierarchical structure of risk factors for a general construction project, determining the assessment factors weights, and getting the synthetic judgment value.

2.1Constructing the Hierarchical Structure of Risk Assessment Factors

Many researchers have tried to tackle the problems of risk and uncertainty identification in construction projects. Chapman [7] define the sources of risk as a risk hierarchy composed of four “layers”: the environment, the industry, the client and the project. Wideman [30] has compiled a risk identification breakdown structure as a framework of the major sources of risk which is subdivided into five classifications of risk: external unpredictable, external predictable but uncertain, internal (non-technical), technical and legal. Smith and Bohn [24] classified project risk into eight broad categories: natural risks, design risks, logistic risks, financial risks, legal and regulatory risks, political risks, construction risks and environment risks. Raftery [21] considers that there are three separate areas of risk: risk internal to the project, risk external to the project, and the client/the project/project team and project documentation. Conroy and Soltan [10] refer to four categories of risk, namely human failings, organizational failings, design group failings and design process failings. Charoenngam and Yeh [8] categorized construction risks into six groups: construction related, performance related, physical, financial and economic, contractual and legal, political and societal. Tah and Carr [25] [26] built a hierarchical risk-breakdown structure, which separated project risk into two main groups: external risk (including economic, physical, political and technological change) and internal risk (including five sub-items in local risk and eleven items in global risk). Thompson and Perry [27] listed sixteen sources of risk, five of which related to construction and three to finance issues.

The assessing hierarchical structure for project risk and uncertainty should provide evaluators the convenience for practical usage and easy understanding. Therefore, the assessment structure should avoid too complex on risk factors and the hierarchy need to express the basic risk and uncertainty condition for a project. The key dimensions and the factors for construction project risk assessing were derived through previous literature review, comprehensive investigation and consultation with several experts, including one professor in architectural engineering, one professor in civil engineering, one experienced contractor. There are five risk and uncertainty dimensions, including economic and financial, contractual and legal, physical and construction related, managerial and performance related, political and societal. From these, twenty assessing factors for the hierarchical structure were used in this study. The hierarchical structure adopted in this study is shown in Fig. 1.

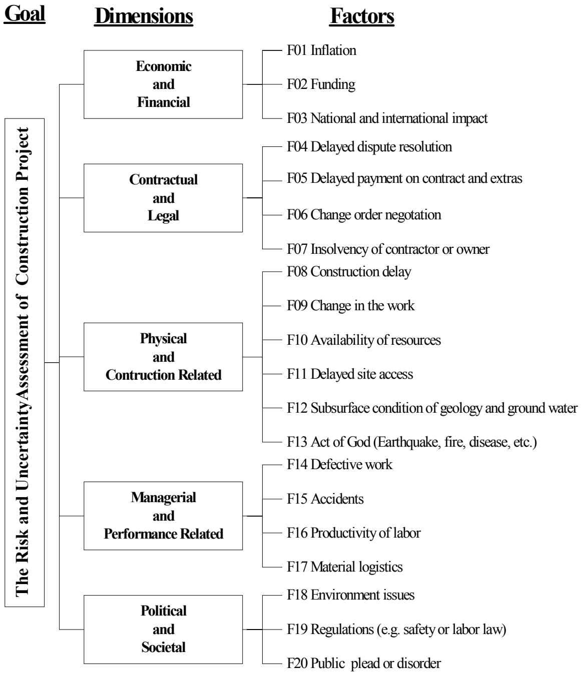


Fig. 1 The Hierarchical Structure for Risk Assessment of Construction Project

2.2Determining the Risk Assessment Factors Weights

Several criteria are used in judging whether the level of risk is high or low, such as the degree of seriousness and the subsequent impact if this risk factor does occur. In this study the impact which is the degree of seriousness and the scale of the impact on project activities if the undesirable thing occurs [35]. However, the factors of project risk and uncertainty assessing have diverse significance and meanings, we cannot assume that each assessing factor is of equal importance. There are many methods that can be employed to determine weights [14] such as the eigenvector method, weighted least square method, entropy method, AHP, and LINMAP (linear programming techniques for Multidimensional of Analysis Preference). The selection of method depends on the nature of the problem. To assess project risk impact is both a complex and wide-ranging problem, so this problem requires the most inclusive and flexible method.

Since the AHP method can systematize complicated problems, is easy to operate, and integrates the experts' or evaluators' opinions. Therefore, in this study, the AHP method to assess the impact of risk factors is suggested. AHP weightings are mainly determined by evaluators who conduct pairwise comparisons of all factors with respect to certain criteria, deals with the relative priority or importance of each factor [22] [23]. The process of determining the importance order among criteria (risk assessment factors) is based on matrix computations and involves pairwise comparison of the various criteria in pairwise comparison matrix such as follow:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}$$

A matrix $\boldsymbol{A} = (a_{ij})$ where $i, j = 1, \cdots, n$, is established for evaluation of criteria and each criterion, a_i is compared with another criterion, a_j. The importance of one criterion over the other is established by utilizing a predetermined scale (refer to Table 1), thus defining $a_{ij} = w_i / w_j$, where w_i / w_j signifies the importance (or weight) of criterion a_i over criterion a_j and $i, j = 1, \cdots, n$. All entries in this matrix are positive and by definition satisfy the condition for a reciprocal matrix,. $a_{ji} = 1/a_{ij}$

Table 1 Comparison scale

Degree of importance	Definition
1	Equal importance of elements
3	Weak importance of one element over another
5	Strong importance of one element over another
7	Demonstrated or very strong importance of one element over another
9	Absolute importance of one element over another
2，4，6，8	Intermediate values between two adjacent degrees of importance

The pairwise comparison of criteria based on the predetermined scale and its organization in a matrix form facilitates further analysis of the information. The relative comparisons of various criteria represent the elements, a_{ij}, of the upper triangle of the comparison matrix. The lower triangle of the matrix is established by taking the corresponding reciprocals from the upper triangle. The relative importance of criteria or the priority vector is established by computing the eigenvector corresponding to the maximum eigenvalue of the comparison matrix. It is important that consistency should be maintained during the pairwise comparisons, that is, $a_{jk} = a_{ik} / a_{ij}$ where $i, j, k = 1, \cdots, n$. Analytical Hierarchy Process allows for reasonable deviations in consistent comparison and does not require the consistency to be in exact mathematical proportions. The consistency of (n × n) matrix can be established by computing the consistency ratio ($C.R.$) for the matrix, as defined in Eqs. (1) and (2).

$$\text{Consistency Ratio}\,(C.R.) = \frac{C.I.}{R.I.} \tag{1}$$

$$\text{Consistency Index}\,(C.I.) = \frac{\lambda_{\max} - 1}{n - 1} \tag{2}$$

where, Random Index ($R.I.$) is defined as the average $C.I.$ for a large number of reciprocal matrices of the same order with random entries, and $\lambda_{\max}$ is the maximum eigenvalue of the matrix under consideration. Empirical studies conducted by Saaty have indicated that a deviation in consistency ratio of less than 10% is acceptable without adversely affecting the results. If the consistency ratio for a matrix is greater than 0.1 then, either the values in the matrix should be rejected or else, steps should be taken to modify the pairwise comparisons till an acceptable consistency ratio is obtained. The procedure for AHP can be summarized in seven steps as follows:

Step 1 Set up the hierarchy system by decomposing the problem into hierarchy of interrelated elements.

Step 2 Construct pairwise comparison matrices among all the elements in the dimensions of the hierarchy system. Assign the ratio values to the pairwise comparisons by asking which is the more important of each two factors.

Step 3 Solves the eigenvector of the comparison matrix and establishes the relative weight for the dimensions level.

Step 4 Check for consistency of the matrix.

Step 5 Repeat Steps 3 and 4 at all descending factor levels of the hierarchy.

Step 6 Multiply the weights of the factors at the upper levels down to the factors at the lower levels along with their vertical relationship.

Step 7 Determine the aggregate relative weights of the decision elements to arrive at a set of ratings for the decision alternatives/strategies.

The final importance weight of every factor provides a basis for considering the priority of the impact to the various risks in a certain kind of construction project.

2.3Getting the Synthetic Judgment Value

In daily life, we often hear people to express their opinion with “not very clear”, “probably so”, or “very likely”, indicating that they have some uncertainty or imprecise judgment. With different daily decision-making problems of diverse intensity, the results can be misleading if the fuzziness (vagueness/uncertainty) of human decision-making is not taken into account. However, since Zadeh put forward fuzzy theory [32], and Bellman and Zadeh [3] described the decision-making method in fuzzy environments, an increasing number of studies have dealt with uncertain fuzzy problems by applying fuzzy set theory. Owing to a construction project often belong to uniqueness, inconsistency and data incompleteness. It is not easy to search available numerical information related to risk factors from another projects since the lack of historical records reservation in many cases. Therefore, the main way to estimate possibility of a risk factor occurrence for an activity of project is subjective judgment by project managers or experts. Since the subjective judgment is a fuzzy behavior in decision-making. Thus, this study includes fuzzy decision-making theory, considering the possible fuzzy subjective judgment of the evaluators during their evaluation of the construction project activities. The applications of fuzzy theory in this study are elaborated as follows:

a. Fuzzy Numbers

Fuzzy numbers are a fuzzy subset of real numbers, representing the expansion of the idea of the confidence interval. According to the definition of Dubois and Prades [12], fuzzy numbers should possess the following basic features.

Fuzzy number $\tilde{A}$ is of a fuzzy set, and its membership function is $\mu_{\tilde{A}}(x)$: $R \to [0,1]$, and it is enshrined with the following characteristics:

(i) $\mu_{\tilde{A}}(x)$ is a continuous mapping from R to the closed interval [0,1];

(ii) $\mu_{\tilde{A}}(x)$ is a convex fuzzy subset;

(iii) $\mu_{\tilde{A}}(x)$ is the normalization of a fuzzy subset, which means that there exists a number x_0 that makes $max\mu_{\tilde{A}}(x_0)=1$.

Those numbers that can satisfy these requirements will then be called fuzzy numbers, and the following is an explanation for the characteristics and the operation of a triangular fuzzy number $\mu_{\tilde{A}}(x)=(L, M, U)$ as shown in equation (3).

$$\mu_{\tilde{A}}(x)=\begin{cases}(x-L)/(M-L) & L\le x\le M\\ (U-x)/(U-M) & M\le x\le U\\ 0 & otherwis\end{cases} \tag{3}$$

Moreover, the set of elements that belong to the fuzzy set $\tilde{A}$ at least to the degree α is called α-level set :

$$\forall\alpha\in[0,1],\ \tilde{A}\ of\ \alpha-cut\ shows\ {}^{\alpha}\tilde{A},\ and$$

$${}^{\alpha}\tilde{A}=[(M-L)\alpha+L,\ -(U-M)\alpha+U]=[{}^{\alpha}L,\ {}^{\alpha}U] \tag{4}$$

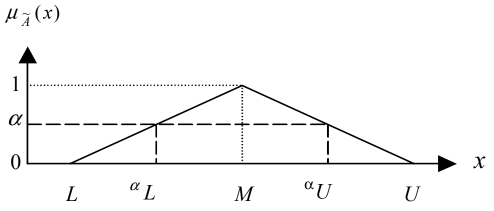


Figure 2. The membership function of the triangular fuzzy number

b. Linguistic Variable

According to Zadeh [33], it is very difficult for conventional quantification to express reasonably those situations that are overtly complex or hard to define; thus, the notion of a linguistic variable is necessary in such situation. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. For example, the expressions of occurrence possibility of risk factors as “inflation,” “change order negotiation, “delayed site access,” “accidents,” “public plead or disorder,” and so on all represent a linguistic variable in the context of this study. Linguistic variables may take on effect-values such as “very high”, “high”, “fair”, “low”, “very low”. Triangular fuzzy numbers, as shown in Fig. 3, can indicate the membership functions of the expression values. The use of linguistic variables is currently widespread, and the linguistic values found in this study are primarily used to assess the linguistic ratings given by the evaluators. Furthermore, linguistic variables are used as a way to measure the scope of occurrence possibility for each risk factor.

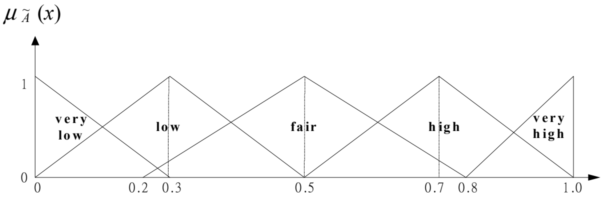


Fig. 3 Membership Function of the Five Levels of Linguistic Variables

c. Fuzzy Multiple Criteria Decision-Making (FMCDM)

Bellman and Zadeh[3] were the first to probe into the decision-making problem under a fuzzy environment, and they heralded the initiation of FMCDM. This study uses this method to evaluate and rank the degrees of risk for construction project activities. The following will be the method and procedures of the FMCDM theory.

(1) Measurement criteria: Using the measurement of linguistic variables to demonstrate the risk factors possibility by expressions such as “very high”, “high”, “fair”, “low”, “very low ”, the evaluators are asked for conduct their subjective judgments, and each linguistic variable can be indicated by a triangular fuzzy number (TFN) within the scale range of 0-1.0. In addition, the evaluators can subjectively assign their personal range of the linguistic variable. Take E_{ij}^{k} to indicate the fuzzy possibility value of

evaluator k towards activity i under factor j, and all of the assessment factors will be indicated by set S, then,

$$E_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}), \quad j \in S \tag{5}$$

Since the perception of each evaluator varies according to the evaluator's experience and knowledge, and the definitions of the linguistic variables vary as well, if there are several evaluators in assessment process, this study uses the notion of average value to integrate the fuzzy judgment values of m evaluators, that is,

$$E_{ij} = (1/m) \otimes (E_{ij}^{1} \oplus E_{ij}^{2} \oplus \ldots \oplus E_{ij}^{m}) \tag{6}$$

The sign $\otimes$ denotes fuzzy multiplication, the sign $\oplus$ denotes fuzzy addition, and Eij shows the average fuzzy number of the judgment of the decision-maker, which can be displayed by a triangular fuzzy number as follows:

$$E_{ij} = (LE_{ij}, ME_{ij}, UE_{ij}) \tag{7}$$

The preceding end-point values LE_{ij}, ME_{ij}, and UE_{ij} can be solved by the method put forward by Buckley [4], that is,

$$LE_{ij} = (\sum_{k=1}^{m} LE_{ij}^{k}) / m \tag{8}$$

$$ME_{ij} = (\sum_{k=1}^{m} ME_{ij}^{k}) / m \tag{9}$$

$$UE_{ij} = (\sum_{k=1}^{m} UE_{ij}^{k}) / m \tag{10}$$

(2) Fuzzy synthetic judgment: The weights of the each risk assessment factor of construction project as well as the fuzzy possibility values must be integrated by the calculation of fuzzy numbers so as to be located at the fuzzy synthetic judgment value (effect-value) of the integral assessment. According to the weight w_j derived by AHP, the weight vector can be obtained, whereas the fuzzy possibility matrix $\boldsymbol{E}$ of each of the activities can also be obtained from the fuzzy judgment value of each activity under n criteria, that is,

$$\boldsymbol{w} = (w_1, \ldots, w_j, \ldots, w_n)^t \tag{11}$$

$$\boldsymbol{E} = (E_{ij}), \ \forall\, i, j \tag{12}$$

From the weight vector $\boldsymbol{w}$ and fuzzy possibility matrix $\boldsymbol{E}$, the final fuzzy synthetic judgment can be conducted, and the derived result will be the fuzzy synthetic judgment matrix $\boldsymbol{R}$, that is,

$$\boldsymbol{R} = \boldsymbol{E} \circ \boldsymbol{w} \tag{13}$$

The sign " ◦ " indicates the calculation of the fuzzy numbers, including fuzzy addition and fuzzy multiplication. Since the calculation of fuzzy multiplication is rather complex, it is usually denoted by the approximate multiplied result of the fuzzy multiplication, and the approximate fuzzy number R_i, of the fuzzy synthetic decision of each alternative can be shown as follows:

$$R_i = (LR_i, MR_i, UR_i), \ \forall\, i \tag{14}$$

$$LR_i = \sum_{j=1}^{n} LE_{ij} * w_j \tag{15}$$

$$MR_i = \sum_{j=1}^{n} ME_{ij} * w_j \tag{16}$$

$$UR_i = \sum_{j=1}^{n} UE_{ij} * w_j \tag{17}$$

(3) Ranking the fuzzy number: The result of the fuzzy synthetic judgment reached by each activity is a fuzzy number. Therefore, it is necessary that a nonfuzzy ranking method for fuzzy numbers be used for during the project risk judgment for each activity. In other words, the procedure of defuzzification is to locate the Best Nonfuzzy Judgment value (BNJ). Methods of such defuzzified fuzzy ranking generally include mean of maximal (MOM), center of area (COA), and α-cut [17][34]. To utilize the COA method to find out the BNJ is a simple and practical method, and there is no need to bring in the preferences of any evaluators, so it is used in this study. The BNJ value of the fuzzy number R_i can be found by the following equation:

$$BNJ_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i, \ \forall i \tag{18}$$

According to the value of the derived BNJ_i for each of the project activities, it ranks the degrees of risk for the project activities and provides a basis for considering the priority of the response to the activities in a construction project.

3.FRAMEWORK OF THE SYSTEM

When developing a framework for the DSS, it is important to realize that various tasks must be assigned to either the computer or the user. In other word, it has to be determined which activities are the responsibility of the decision maker (user input) and which are the best handled by the computational system (system requirements)[19]. Based on the procedures mentioned in section above, we developed an integrated system of AHP and FMCDM to perform the assessment of construction project risk. Since iteration of the process is required, a spreadsheet application lends itself as a logic choice for the application tool. Microsoft Excel was selected as the spreadsheet application tool for the decision support system. The process diagram of AHP and FMCDM for assessing the degree of risk of each activity in this study is shown as Fig 4. Then, the main interfaces of the system are shown as Fig.5 to Fig. 15.

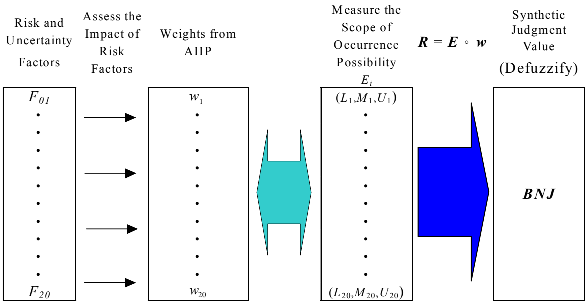
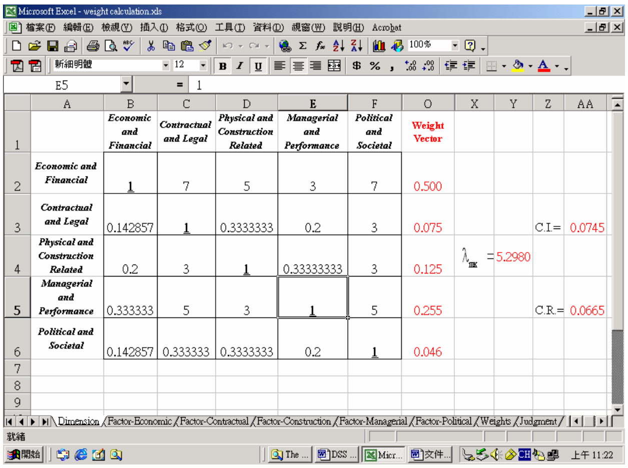


Fig. 4 Diagram of AHP and FMCDM for Assessing the Degree of Risk of Each Activity



E5 = 1

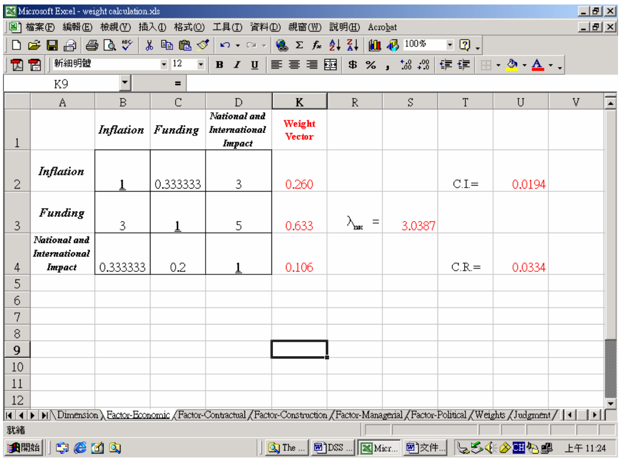
	Economic and Financial	Contractual and Legal	Physical and Construction Related	Managerial and Performance	Political and Societal	Weight Vector
Economic and Financial	1	7	5	3	7	0.500
Contractual and Legal	0.142857	1	0.3333333	0.2	3	0.075
Physical and Construction Related	0.2	3	1	0.33333333	3	0.125
Managerial and Performance	0.333333	5	3	1	5	0.255
Political and Societal	0.142857	0.333333	0.3333333	0.2	1	0.046

C.I.= 0.0745

$\lambda_{\max}$ = 5.2980

C.R.= 0.0665

Fig. 5



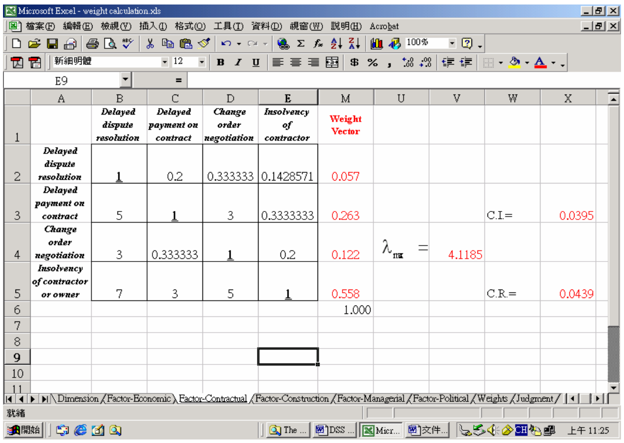
	Inflation	Funding	National and International Impact	Weight Vector
Inflation	1	0.333333	3	0.260
Funding	3	1	5	0.633
National and International Impact	0.333333	0.2	1	0.106

C.I.= 0.0194

$\lambda_{\max}$ = 3.0387

C.R.= 0.0334

Fig. 6



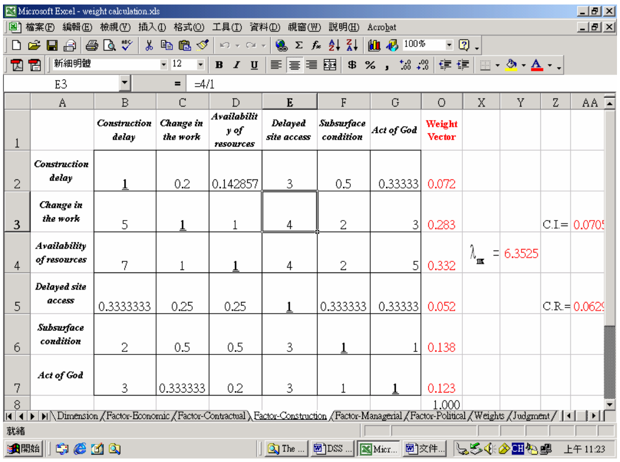
	Delayed dispute resolution	Delayed payment on contract	Change order negotiation	Insolvency of contractor	Weight Vector
Delayed dispute resolution	1	0.2	0.333333	0.1428571	0.057
Delayed payment on contract	5	1	3	0.3333333	0.263
Change order negotiation	3	0.333333	1	0.2	0.122
Insolvency of contractor or owner	7	3	5	1	0.558
					1.000

C.I.= 0.0395

$\lambda_{\max}$ = 4.1185

C.R.= 0.0439

Fig. 7



E3 = =4/1

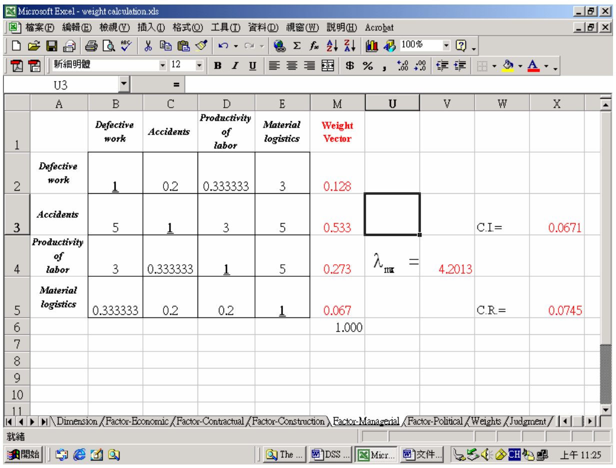
	Construction delay	Change in the work	Availability of resources	Delayed site access	Subsurface condition	Act of God	Weight Vector
Construction delay	1	0.2	0.142857	3	0.5	0.33333	0.072
Change in the work	5	1	1	4	2	3	0.283
Availability of resources	7	1	1	4	2	5	0.332
Delayed site access	0.3333333	0.25	0.25	1	0.333333	0.33333	0.052
Subsurface condition	2	0.5	0.5	3	1	1	0.138
Act of God	3	0.333333	0.2	3	1	1	0.123
							1.000

C.I.= 0.070

$\lambda_{\max}$ = 6.3525

C.R.= 0.062

Fig. 8



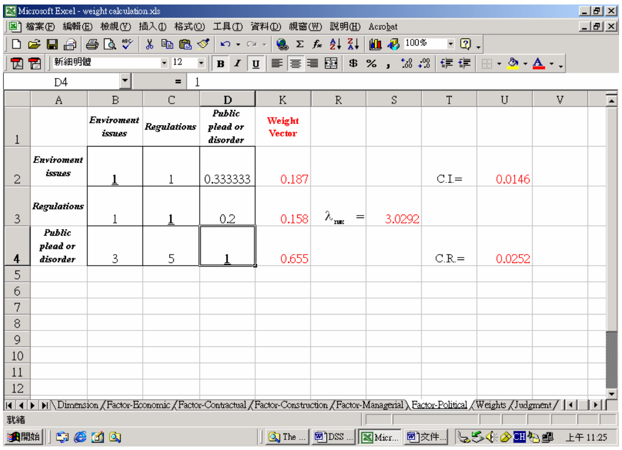
	Defective work	Accidents	Productivity of labor	Material logistics	Weight Vector
Defective work	1	0.2	0.333333	3	0.128
Accidents	5	1	3	5	0.533
Productivity of labor	3	0.333333	1	5	0.273
Material logistics	0.333333	0.2	0.2	1	0.067
					1.000

C.I.= 0.0671

$\lambda_{\max}$ = 4.2013

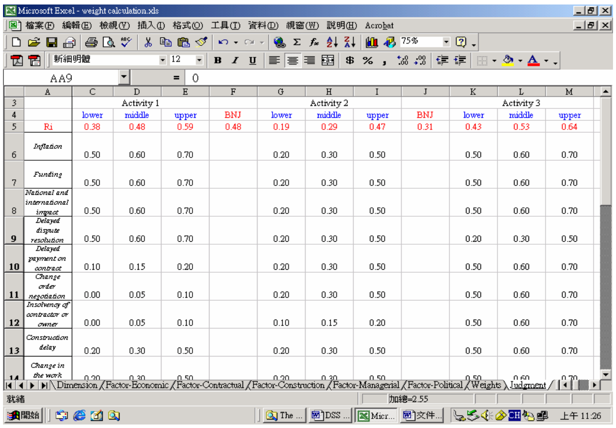
C.R.= 0.0745

Fig. 9



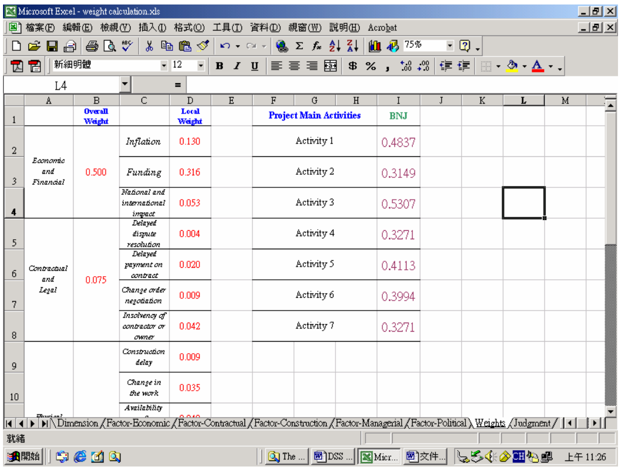
	A	B	C	D	K	R	S	T	U
1		*Enviroment issues*	*Regulations*	*Public plead or disorder*	**Weight Vector**				
2	*Enviroment issues*	1	1	0.333333	0.187			C.I.=	0.0146
3	*Regulations*	1	1	0.2	0.158	λ_{max} =	3.0292		
4	*Public plead or disorder*	3	5	1	0.655			C.R.=	0.0252

Fig. 10



	A	C	D	E	F	G	H	I	J	K	L	M
3		Activity 1				Activity 2				Activity 3		
4		lower	middle	upper	BNJ	lower	middle	upper	BNJ	lower	middle	upper
5	Ri	0.38	0.48	0.59	0.48	0.19	0.29	0.47	0.31	0.43	0.53	0.64
6	*Inflation*	0.50	0.60	0.70		0.20	0.30	0.50		0.50	0.60	0.70
7	*Funding*	0.50	0.60	0.70		0.20	0.30	0.50		0.50	0.60	0.70
8	*National and international impact*	0.50	0.60	0.70		0.20	0.30	0.50		0.50	0.60	0.70
9	*Delayed dispute resolution*	0.50	0.60	0.70		0.20	0.30	0.50		0.20	0.30	0.50
10	*Delayed payment on contract*	0.10	0.15	0.20		0.20	0.30	0.50		0.50	0.60	0.70
11	*Change order negotiation*	0.00	0.05	0.10		0.20	0.30	0.50		0.50	0.60	0.70
12	*Insolvency of contractor or owner*	0.00	0.05	0.10		0.10	0.15	0.20		0.50	0.60	0.70
13	*Construction delay*	0.20	0.30	0.50		0.20	0.30	0.50		0.50	0.60	0.70
14	*Change in the work*	0.20	0.30	0.50		0.20	0.30	0.50		0.50	0.60	0.70

Fig. 11



	A	B	C	D	F–H	I
1		**Overall Weight**		**Local Weight**	**Project Main Activities**	**BNJ**
2	*Economic and Financial*	0.500	*Inflation*	0.130	Activity 1	0.4837
3			*Funding*	0.316	Activity 2	0.3149
4			*National and international impact*	0.053	Activity 3	0.5307
5	*Contractual and Legal*	0.075	*Delayed dispute resolution*	0.004	Activity 4	0.3271
6			*Delayed payment on contract*	0.020	Activity 5	0.4113
7			*Change order negotiation*	0.009	Activity 6	0.3994
8			*Insolvency of contractor or owner*	0.042	Activity 7	0.3271
9			*Construction delay*	0.009		
10			*Change in the work*	0.035		
			Availability			

Fig. 12

4.CONCLUSION

General speaking, more preparation in advance will get less loss on operation. Thus, this work provides a systemic model to assess the factors of risk of a construction project may encounter, and according to the results of assessment to plan the risk management strategies for construction activities. It is helpful to contractor recognize what risk factors he will face and how to plan a risk management strategies when was awarding a large-scale construction contract. The purpose of this study was to develop a scientific framework and computer-based decision support system for the risk assessment of construction project. This work proposes a multi-criteria framework for risk assessment. To deal with the qualitative attributes in subjective judgment, this work employs Analytic Hierarchy Process (AHP) to determine the weights of risk factors. Then, the Fuzzy Multiple Criteria Decision Making (FMCDM) approach is adopted to synthesize the degree of risk of each activity. This process enables decision makers to formalize and effectively solve the complicated, multicriteria and fuzzy/vague perception problem of project risk assessment. An integrated decision support system that combines the AHP method and FMCDM approach to be effective and convenient for assessing the degree of risk by a popular program-EXCEL. It will assist the project managers in making critical decisions during the phase of project contracting and construction.

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