RISK IDENTIFICATION AND MEASUREMENT OF BOT PROJECTS

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Abstract: The purpose of this paper is to analytically measure and rank risk of BOT projects for decision making under an uncertain environment. The individual and group multi-attribute risk utility functions in the risk measurement model are developed based on multiattribute decision making and utility theorems. The preference of the negotiator is considered in the multiattribute risk utility function. The risk event is obtained by the model when the group risk utility value is smaller than the expected risk utility value. Futhermore, the critical risk event is obtained when the group multiattribute risk utility value is not less than the expected utility. In addition the risk measurement model provides an approach to quantify, identify and find critical risk, and to incorporate the preference of the decision-maker in order to share risk under BOT negotiation.
Key Words: BOT; risk identification; critical risk; risk measurement; uncertainty

1. INTRODUCTION

Transportation infrastructure development projects have the following characteristics: large civil works budget, substantial land acquisition over a large area, long construction time frame, large labor force, complex internal government coordination, and multi-national construction/design teams. Few transportation development projects are profitable or self-financing on the basis of user fees only, because of complicating factors such as high capital cost, lengthy construction period with no revenues, and low to moderate fare level favored by government. BOT (Build, Operate and Transfer), one method of privatization, is an approach where the private sector is given a concession to design, construct, finance, manage and operate a project that would normally be built and operated by the government, and transfers ownership of the project back to the government at the end of the concession period. Some important reasons for governments to use the approach are to reduce the government's financial burden, to use the private sector's technological know-how, management skills and capital, and to transfer most of the project risks to the private sector.

Since both the government and private sector will take part in a BOT project, the complex contractual negotiation requires considerable cost and time and becomes an important subject of BOT projects. Identification and measurement of risk is fundamental to risk allocation and sharing, which is the basis of contractual negotiation between the government and concession company (Tiong, 1992, 1995, 1996, 1997; Sidney, 1996; Walker and Smith, 1996). Normally, the government wants to transfer most of risk to private sector while the concession company expects to reduce its exposure to risk (Levitt, *et al.* 1980). Philip (1995), Nicole (1995), Tiong (1990, 1995), and Walker and Smith (1996) have discussed different types of risks BOT projects are exposed to, but risk measurement and risk identification are not explored.

Different projects have their own risk profile, although in general there are political risks, commercial risks, legal risks, construction/completion risks, operation risks, etc. How to measure the degree of risk? and how to distinguish between major and minor risk? are the issues this paper will explore. Tiong (1990, 1995) and Tiong and Yeo (1992) have shown that risk analysis is an important issue for BOT projects particularly during the period of bidding, contract negotiation and risk management. Hwang (1995) has employed the notion of property rights to elucidate the essence of BOT projects, and to illustrate their optimal risk level by means of transaction cost and probability distribution. The results show that the optimal risk of the investment is in positive, indeterminable, or negative relationship to the investment rate of return and that the BOT contract is a non-zero-sum game which is completely different from the zero-sum game. They also show the different relationship between risk and investment return but do not show what level of risk is critical. William and Crandall (1982) considered the attributes of risks, suggesting that the risk measurement of infrastructure projects must consider the attributes of risk events. The risk negotiation was affected by risk attributes and the negotiator's preference (Seo and Sakawa, 1985, 1990). Following the concepts of Seo and Sakawa, this paper will focus on risk measurement and risk identification.

Quantitative and qualitative methods have been used to discuss or measure risk, in past research. Financial risk analysis (Cuthbertson, 1996), utility analysis (Jia and Dyer, 1996; Seo and Sakawa, 1984, 1985, 1990), statistical analysis (Louis, 1990; Jaselskis and Russell, 1992; Ronald, 1990), and expert investigation (Mustafa and Al-Bahar, 1991) were used to analyze risk in the quantitative analysis field. The indices in financial risk analyses, such as the NPV, B/C ratio and IRR, have been widely used for measurement of financial conditions, but they have difficulty estimating future cash flow. Therefore, financial risk analysis is properly applied to evaluate only short-term projects with a certain environment. As for the BOT project with high uncertainty and with a long concession time, it is difficult to accurately estimate cash flow (Sidney, 1996). In addition, the major problem is to determine what level the risk of loss is? Is it 1 million dollars or 1 billion dollars? This problem is hard to answer by NPV. Although the B/C and IRR ratio have an index value from 0 to 1, the index value cannot reflect the different levels of risk for different events.

Buhlman (1996), Ronald (1990), Louis (1990), Jia and Dyer (1996), and Hwang (1995) use the statistical approach to measure risk. The expected value is obtained where the risk probability distribution has a supposed specific distribution. We think the problem lies in what kind of distribution can fit the probability for BOT projects with thirty years concession time, as well as what type of independent or dependent relationships among the risks will lead to measurement error in expected value of loss. As for the utility approach, it is liable to be applied on certainty or uncertainty, and it cannot estimate future cash flow. The approach is especially suited to considering the negotiator's preference in order to reflect the risk preference during contract negotiation (William and Keith, 1982; Seo and Sakawa, 1984, 1985). Also, the utility approach easily judges with the value between 0 and 1. In addition, Seo and Sakawa have constructed a risk utility function and introduced the fuzzy concept into risk analysis so as to render it more fitting to uncertain negotiation behavior. Seo and Sakawa (1985, 1990) have focused on the preference change for the decision maker's behavior, but they have not defined the risk by using the utility theorem. Jia and Dyer (1996) have developed risk measurement as $R(X)=-E[u(X-\bar{X})]$, and this study provides the concept of a negative expected utility in preference. The $u(X-\bar{X})$ is a normalization value in mean, where X is a probability distribution and $R(X)$ is a risk measure, but the equations do not consider the stability in measuring risk for factors deriving from different risks, events, attribute samples, etc. In addition, the normalization value in $X-\bar{X}$ results in a positive or negative value, and thus, $R(X)$ value will not hold to only one value.

Expert investigation is a method to measure risk and the AHP method has been used to evaluate risk in criteria construction (Mustafa and Al-Bahar, 1991). The AHP approach captures the weight value from project experts, engineers or project managers and then, based on the weight of experts and performance value, measures risk value. Nonetheless, the weight and performance value obtained from AHP can hardly demonstrate genuine risk. Moreover, there are different risks for each construction project, the criteria and goals have different importance and hence, the hierarchical structure alone can't indicate the unique conditions of the event.

The purpose of this paper is to analytically identify and measure risk, and to determine the critical risk for the government or BOT concession company. In order to take preference and risk attributes into account, this paper uses multiattribute decision making and utility theorem to construct a multiple attribute utility function to illustrate the measurement of risk, identification of risks and critical risk events

The remainder of this paper is organized as follows: section 2 describes the problem, defines the risk and uncertainty, and develops the multiattribute risk utility function; section 3 develops the group utility function; section 4 analyzes the risk of the BOT contract; and conclusions are made in the final section.

2. MODEL DEVELOPMENT

In this section, we will describe the problem of this study, define the risk and uncertainty, and develop the individual risk utility function in order to establish a group negotiation risk utility function.

2.1 The Problem Description

An Airport-Link Rapid Transit project between CKS Airport and Taipei city will be undertaken by BOT approach in Taiwan. The BOT concession company and government are in contract negotiation for this BOT project as bidding for this transportation infrastructure project recently finished. There are two groups taking part in negotiations, one is the government group and the other is the BOT private group. The government group includes some individual negotiators from other government departments, such as the MOTC (Ministry of Transportation and Communications), EPA (Environment Protection Administration), city government, etc. Also the BOT private group has some individual negotiators including lawyers, financial consultants, participators, participant companies, etc. It must be clarified here, that the two primary negotiators of this contract are groups rather than individuals (see Figure 1). The conditions of contract must be acceptable to both parties, otherwise, the BOT project will be terminated.

In the past, most researches qualitatively identify risks from events, however, risk and uncertainty should be strictly treated different. In addition, what are the critical or important risk items should also be a main issue for negotiators during the period of bidding, negotiation and risk mitigation. This paper aims at developing an approach to decompose the set of event into the set of uncertainty and risk, and furthermore to decompose the set of risk items to critical risks and general risks (see Figure 2).

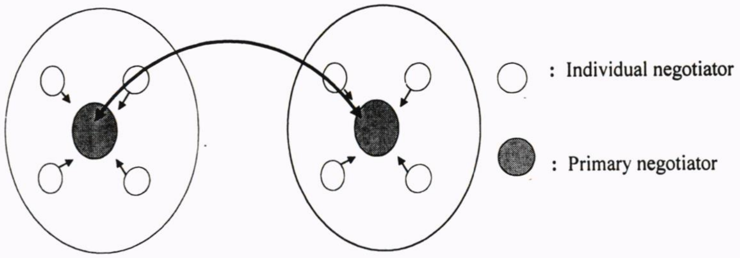

Figure 1. Primary Negotiators and Individuals

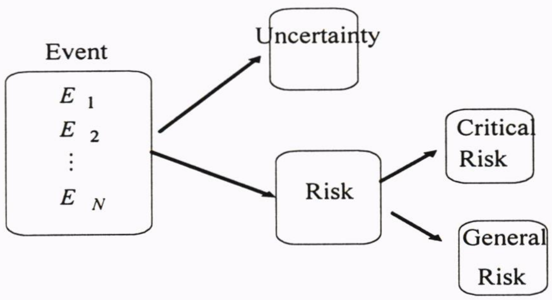

Figure 2. Event, Uncerrtainty, Risk and Critical Risk

2.2 Basic Assumptions

In this paper, some assumptions for model development are as follows:

(1).The asymmetric information does not exist between the negotiation group and individual negotiator.

(2).The deeision-making behavior of individual negotiators within the negotiation group is reasonable.

(3).The probability of event occurrence is assumed to be a Bernoulli experiment and the probability of occurrence is the probability of success.

2.3 Model Development

(1). Risk and uncertainty definition

Based on the literature mentioned above, where variance is greater, the risk is higher and where there is a greater difference between actual occurrence and expectation, there will be greater loss. Considering the stability of risk, the risk and uncertainty definition will be expressed as the following:

(a). Risk definition
Since the dislike events will result in lower utility for decision maker, the risk will be defined as a specific event which will result in lower preference for the decision maker. This interprets the occurrence of risk, the loss of preference and the tolerance of choice. Risk R_E is defined as Eq. (1):

$$R_E \equiv u_j(x_j) < \bar{u}(x) \tag{1}$$

where $u_j(x_j)$ is the utility function of outcome x_j for specific event E, $0 \le u_j(x_j) \le 1$, $\bar{u}(x)$ is the expected utility value for specific event E, $\bar{u}(x) = \sum_j p_j u_j(x_j)$, p_j is the probability of outcome x_j; Eq. (1) implies that the event E has risk when the utility function of outcome x_j for the decision maker is less than expected utility value for event E.

(b). Uncertainty definition
In contrast to risk, uncertainty will be defined as a specific event which will not result in lower preference for the decision maker. The equation can be expressed as Eq. (2).

$$UR_E \equiv (u_j(x_j)) \ge \bar{u}(x) \tag{2}$$

where the variables $u_j(x_j)$ and $\bar{u}(x)$ are defined as above. The $u_j(x_j)$ value will be $0 \le u_j(x_j) \le 1$.

(2). The risk utility function of the individual decision maker

The risk utility function proposed in this study was based on the multiattribute theory and utility function. The single attribute and multiattribute of a specific event are considered in the risk utility function.

(a). Transformation of the variable
Based on the utility theorem of Keeney and Raiffa (1993), the utility or preference for an event or alternative should be a positive value, that is $0 \le u_j(x_j) \le 1$. This paper proposes the utility transformation variable to satisfy the condition of a utility value between 0 and 1. The utility normalization is defined as Eq. (3).

$$u^*(x_{ij}) = \frac{p_{ij} \times u(x_{ij}) - \min\{p_{ij} \times u(x_{ij})\}}{\max\{p_{ij} \times u(x_{ij})\} - \min\{p_{ij} \times u(x_{ij})\}} \tag{3}$$

where $u^*(x_{ij})$ is the normalized utility value, p_{ij} is the probability of the utility of outcome i and state j, for all $j = 1,2,...,n$, $i = 1,2,...,m$; $u(x_{ij})$ is the utility value of outcome x_{ij}. Since $0 \le u(x_{ij}) \le 1$ and $0 \le p_{ij} \le 1$, the $u^*(x_{ij})$ value will be located between 0 and 1, $0 \le u^*(x_{ij}) \le 1$. Eq. (3) considers a multiattribute case. When $i = 1$, then Eq. (3) becomes a single attribute case.

(b) Single attribute risk utility

Considering a single attribute of a specific event, let E denote the specific event, S has n states for event E, $S = \{s_1, s_2, ..., s_j, ..., s_n\}$, for $j = 1,2,...,n$; X has outcomes x_n under s_n states for event E, $X = \{x_1, x_2, ..., x_j, ..., x_n\}$; $u(X)$ is the utility value of the individual negotiator of outcome x_n for event E; p is the set of probability corresponding to the utility, $p=\{p_1,p_2,...,p_j,...,p_n\}$, $p_j = prob(x_j,s_j)$, $0 \le p_j \le 1$. The structure of state, probability and outcome of the attribute for event E are shown in Table 1.

Table 1 The Structure of State, Probability and Attribute

Event E	States S
	$s_1, s_2, ..., s_j, ..., s_n$
Outcome of attribute X	$x_1, x_2, ..., x_j, ..., x_n$
Utility $u(X)$	$u(x_1), u(x_2), ..., u(x_j), ..., u(x_n)$
Probability P	$p_1, p_2, ..., p_j, ..., , p_n$

For event E, $p_j = \Pr ob(x_j, s_j)$ is the probability of the utility under the outcome x_j and s_j states, $p_{j-1} = \Pr ob(x_{j-1}, s_{j-1})$ is the probability of the outcome under the outcome x_{j-1} and state s_{j-1}. Because there exists a one-to-one relationship among s_j, x_j and p_j, the states s_j and s_{j-1} are mutually independent and the outcome x_j and x_{j-1} are also mutually independent, then $\Pr ob(x_{j-1}, s_{j-1}) \cap \Pr ob(x_j, s_j) = 0$. Based on Table 1, the probability of the utility value is $p_l, p_2, \cdots, p_j, \cdots, p_n$, respectively; the utility mean value is obtained from $\bar{u}(x)$, $\bar{u}(x) = \sum_{j=1}^{n} p_j u(x_j)$; the standard deviation of utility value is $\sigma(u(x_j)) = \sqrt{Var(u(x_j))}$, for all $j = 1,2,..,n$. Based on the concept from Eq. (1), the risk utility function of event E for the g individual negotiator can be shown as Eq. (4).

$$u_g(R_E) \equiv ((u^*(x_j)) < \bar{u}(x) / \sigma((u(x)) \tag{4}$$

where $u_g(R_E)$ is the risk utility function for the g individual negotiator, the risk utility is normalized by $u^*(x_j)$. If $((u^*(x_j)) < \bar{u}(x)/\sigma((u(x))$ then event E is a risk event, since $0 \le u^*(x_j) \le 1$, then $0 \le u_g(R_E) \le 1$. Eq. (4) implies that the event E is a risk event for g individual negotiator when the normalized utility value is smaller than the expected utility value. Otherwise, the event E is an uncertain event.

(c). Multiattribute risk utility

This paper, based on the fundamental single attribute risk utility, will develop the multiattribute risk utility function. Suppose event E has m outcomes and n states, let S be the set of state of event E, $S=\{s_1,s_2,...,s_j,...s_n\}$; X is the set of outcomes $X=\{x_1,x_2,...,x_i,...,x_m\}$, for $i=1,2,...,m$; the probability P is the set of probability corresponding to the utility, $P=\{p_{1j},p_{2j},...,p_{ij},...,p_{mj}\}$, $p_{ij} = \Pr ob(x_{ij}, s_j)$, $0 \le p_{ij} \le 1$, for $j=1,2,..,n$, $i=1,2,...,m$. The relationship between state, probability and attributes is shown in Table 2.

Table 2 The Structure of State, Probability and Attributes

Event	States		Probability	Weight
E	S	$s_1, s_2, \ldots, s_j, \ldots, s_n$	P	w_j
Outcome Of Attribute X	x_1	$x_{11}, x_{12}, \ldots, x_{1j}, \ldots, x_{1n}$		
	$\vdots$	$\vdots \quad \vdots \quad \vdots \quad \vdots$		
	x_i	$x_{i1}, x_{i2}, \ldots, x_{ij}, \ldots, x_{in}$		
	$\vdots$	$\vdots \quad \vdots \quad \vdots \quad \vdots$		
	x_m	$x_{m1}, x_{m2}, \ldots, x_{mj}, \ldots, x_{mn}$		
Utility $u(x)$	$u(x_1)$	$u(x_{11}), \ldots, u(x_{1j}), \ldots, u(x_{1n})$	p_{1j}	w_1
	$\vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots$	$\vdots$
	$u(x_i)$	$u(x_{i1}), \ldots, u(x_{ij}), \ldots, u(x_{in})$	p_{ij}	w_i
	$\vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots$	$\vdots$
	$u(x_m)$	$u(x_{m1}), \ldots, u(x_{mj}), \ldots, u(x_{mn})$	p_{mj}	w_m
Probability	P	$p_{i1} \quad \cdots \quad p_{ij} \quad \cdots \quad p_{in}$		

Let $p_{ij} = \Pr ob(x_{ij}, s_j)$ be probability of utility corresponding to the outcome x_{ij} and state s_j, and $p_{i-1,j} = \Pr ob(x_{i-1j}, s_j)$ is the probability of utility corresponding to the outcome x_{i-1j} and state s_j; because there exists a one-to-one relationship between s_j, x_{ij}, and p_{ij}, thus $\Pr ob(x_{i-1j}, s_j) \cap \Pr ob(x_{ij}, s_j) = 0$. This shows that $p_{i-1,j}$ and $p_{i,j}$ are mutually independent. Let $\bar{u}(x_1) = \sum_{j=1}^{n} p_{1j} u(x_{1j})$ be the expected utility value of outcome x_1, $\bar{u}(x_i) = \sum_{j=1}^{n} p_{ij} u(x_{ij})$ be the expected utility value of outcome x_i, and let $\bar{u}(x) = \sum_{i=1}^{m} w_i \sum_{j=1}^{n} p_{ij} u(x_{ij})$ be the total expected utility value, where w_i is the weight value of utility. $\sigma^2 = Var(u(x)) = E(((u(x_{ij}) - \bar{u}(x))^2)$ is the total variance utility for all $j = 1,2,..,n$, $i = 1,2,\ldots,m$. Then, the multiattribute risk utility function of event E for the g individual negotiator can be shown as Eq. (5).

$$u_g(R_{ME}) \equiv ((u^*(x_{ij})) < \bar{u}(x) / \sigma((u(x)) \qquad (5)$$

where $u_g(R_{ME})$ is the multiattribute risk utility function for the g individual negotiator, the multiattribute risk utility is a normalized value, then the multiattribute risk utility will be between 0 and 1, $0 \le u_g(R_{ME}) \le 1$.

3. THE GROUP RISK UTILITY MODEL

In this section, the concession negotiator multiattribute risk utility function will be established for the BOT concession company and government sector respectively, and the function provided will measure risk, identify risk and find out the critical risk event.

The concepts in Eqs. (4) and (5) provided an individual negotiator for risk measurement and results in a constant value, linear, additive, multiplicative or other function form. Although the individual negotiator's preference can be taken into account in risk utility function, the risk measurement is different between the group and individual negotiators. In addition, the notion must be proposed that event E is a risk event by means of individual risk utility if the risk utility function satisfies Eq. (4). This does not ensure event E is a risk event for the concession group. In other words, this implies that the risk event for the group was determined by group risk utility, not by individual negotiators. The concept of group decision making has previously been discussed by Keeney and Raiffa (1993). Their theory infers that the group utility will be adopted instead of an individual utility when group negotiators are making decisions.

3.1 The Concept of Multiattribute Utility Function

Keeney and Raiffa (1993) proposed the multiattribute utility function (MAU). Based on their concept, the additive and multiplicative methods are appropriate for constructing the group decision-maker's multiattribute utility function. The conditions of this function are: (1) total number of attributes is not less than three, (2) the preference structure of decision-maker is preference independent, and (3) the utility of the decision-maker is preference independent. The fundamental mathematical equation for the multiattribute utility function can be expressed as Eq. (6).

$$U(X) = \sum_{i=1}^{n} k_i U_i(x_i) \tag{6}$$

where $U_i(x_i)$ is a single attribute utility function, $0 \le U_i(x_i) \le 1$; U is a multiattribute utility function; k_i is a scaling constant, and $0 \le k_i \le 1$. In Seo's (1990) study, which constructed the fuzzy multiattribute risk function for group decision making based on the concepts of Keneey and Raiffa, the assumptions were event independent, aversion independent and trade-off attribute independent because of his modified MAU theorem. The reason he made the assumptions was to consider the hazard for decision-makers when the event occurs under an uncertain environment.

3.2 The Group Negotiation Risk Utility Function

(1). Multiattribute risk utility function for the government sector

Suppose the government group has g negotiators, risk utility function $u_g(R_E)$ exists for each g individual negotiator, for $g = 1,2,\ldots,h$. Assume the negotiators' utility, trade-off attribute, and events are independent. Following the concept of MAU and risk function constructed by Seo (1990), the group risk utility function for government was employed by this study, and is expressed as Eq. (7).

$$\begin{aligned} U_g^E &= U_g^E(u_1(R_1^E), u_2(R_2^E), \ldots, u_g(R_g^E)) = \sum_{g=1}^{h} k_g u_g(R_g^E) + k \sum_{g=1}^{h} \sum_{a>g} k_{ag} u_g(R_g^E) u_a(R_a^E) \\ &+ k \sum_{g=1}^{h} \sum_{a>g} \sum_{b>a} k_{gab} u_g(R_g^E) u_a(R_a^E) u_b(R_b^E) + \cdots + k_{123\cdots h} u_1(R_1^E) u_2(R_2^E) \cdots u_h(R_h^E) \end{aligned} \tag{7}$$

where U_g^E is a group multiattribute risk utility function for event E, $0 \le U_g^E \le 1$; $u_g(R_g^E)$

is a multiattribute risk utility function for risk event E for g individual negotiator; k_g is a scaling constant, and $0 \le k_g \le 1$. If $U_g^E < \bar{u}_g(R_g^E)$, the event E is a risk event for group decision-makers, otherwise, event E is an uncertain event. That means the risk event E is decided by group decision-makers and $\bar{u}_g(R_g^E)$ is defined as expected value risk utility of event E.

(2). Multiattribute risk utility function of BOT concession company

As for the BOT concession company, the group multiattribute risk utility was established by the same concept described above. Suppose the BOT company group has q negotiators, for $q=1,2,...,l$, the risk utility function of event F is $u_q(R_F)$ for q individual negotiator. Also, we assume for the BOT group risk utility function that the negotiators' utility is independent, trade-off attributes are independent, and events are independent. The group risk utility function for the BOT company was employed and is expressed as Eq. (8).

$$U_q^F = U^F(u_1(R_1^F), u_2(R_2^F),..., u_l(R_l^F)) = \sum_{q=1}^{l} k_q u_q(R_q^F) + k \sum_{q=1}^{l} \sum_{a>q} k_{aq} u_q(R_q^F) u_a(R_a^F)$$
$$+ k \sum_{q=1}^{l} \sum_{a>g} \sum_{b>a} k_{qab} u_q(R_q^F) u_a(R_a^F) u_b(R_b^F) + \cdots + k_{123\cdots l} u_1(R_1^F) u_2(R_2^F) \cdots u_l(R_l^F) \quad (8)$$

where U_q^F is a group multiattribute risk utility function for event E; $u_q(R_q^F)$ is a multiattribute risk utility function of g individual negotiator for risk event E; k_q is a scaling constant, and $0 \le k_q \le 1$. Because $0 \le u_q(R_q^F) \le 1$ and $0 \le k_q \le 1$, the U_q^F value will be between 0 and 1. If $U_q^F < \bar{u}_q(R_q^F)$, where $\bar{u}_q(R_q^F)$ is expected value risk utility of event F, then event F is a risk event for q negotiators, $q=1,2,...,l$; otherwise, event F is an uncertain event.

4. RISK ANALYSIS

In this section, the risk event and uncertainty event will be defined, and the risks of the contract will be explored.

4.1 Risk Event and Uncertain Event Definition

The concepts in Eqs. (7) and (8) have illustrated one event becoming a risk event for group negotiators instead for an individual negotiator. Because the risks are independent, the risk and uncertain event can be obtained from Eq. (7) or (8). As for the risk to the government, we can get the risk event and uncertain event one-by-one from Eq. (7). The risk event and uncertain event are defined in Eqs. (9) and (10), respectively.

(1). Risk event definition
If event E exists and $U_g^E < \bar{u}_g(R_g^E)$, then event E is a risk event, as defined by Eq. (9).

$$R_g^E = \{U_g^E < \bar{u}_g(R_g^E)\}, \text{ for } g = 1,2,...,h \quad (9)$$

(2). Uncertain event definition

Based on Eq. (7), if event E exists and $U_g^E \geq \bar{u}_g(R_g^E)$, then event E is an uncertain event.

4.2. Risk Choice and Ranking Risk

(1.) Risk Choice

For the government agency, suppose the group negotiation has g individual negotiators and G events for $G=1,2,...t$, $g=1,2,...,h$, and suppose these G events are independent. The risk can be measured per event by Eq. (7), then the risk event and uncertain event can be obtained in order to collect risk and uncertainty for the G events.

Let Ω^G denote the set of G events. Based on Eq. (7) and event independence, the events Ω^G can be separated from risk and uncertainty. The set of events Ω^G is defined in Eq. (10). Also, the risk event set and the uncertainty event set can be defined in Eqs. (11) and (12), respectively.

$$\begin{aligned}\Omega^G &= \Omega_R^G + \Omega_{NR}^G \\ &= \{R_g^G \mid U_g^G < \bar{u}(R_g^G), \forall G=1,2,..t; g=1,2,...,h\} + \{UR_g^G \mid U_g^G \geq \bar{u}(R_g^G), \forall G=1,2,..t; g=1,2,...,h\}\end{aligned} \tag{10}$$

$$\Omega_R^G = \{R_g^G \mid U_g^G < \bar{u}(R_g^G), \forall G=1,2,..t; g=1,2,...h\} \tag{11}$$

$$\Omega_{NR}^G = \{UR_g^G \mid U_g^G \geq \bar{u}(R_g^G), \forall G=1,2,..t; g=1,2,...h\} \tag{12}$$

As for the BOT concession company, let Π^Q denote the set of Q events for $Q=1,2,...r$ and suppose the event is independent. Based on Eq. (8), the risk event and uncertain event can be obtained for the BOT concession company and expressed by Eq. (12). In addition, the risk event set and the uncertain event set can be defined in Eqs. (14) and (15), respectively, for the BOT concession company.

$$\begin{aligned}\Pi^Q &= \Pi_R^Q + \Pi_{NR}^Q \\ &= \{R_q^Q < \bar{u}(R_q^Q),\ \forall Q=1,2,...,r; q=1,2,...,l\} + \{R_q^Q \geq \bar{u}(R_q^Q),\ \forall Q=1,2,...,r; q=1,2,...,l\}\end{aligned} \tag{13}$$

$$\Pi_R^Q = \{R_q^Q < \bar{u}(R_q^Q),\ \forall Q=1,2,...,r; q=1,2,...,l\} \tag{14}$$

$$\Pi_{NR}^Q = \{R_q^Q \geq \bar{u}(R_q^Q),\ \forall Q=1,2,...,r; q=1,2,...,l\} \tag{15}$$

(2). Rank risk and critical risk

(a) Rank risk

Based on Eqs. (8) and (9), the multiattribute risk utility function of group negotiation can be used to measure risk, and we can find the risk event set Ω_G^R and Π_Q^R of the government and BOT concession company, respectively. Suppose there are O, P, Q, R, and S risk events $O, P, Q, R, S \in \Omega_G^R$, and the risk utility U_g^O, U_g^P, U_g^Q, U_g^R and U_g^S can be obtained by means of equation, Based on the preference utility theorem, if the degree of risk utility is $U_g^S \prec U_g^O \prec U_g^P \prec U_g^Q \prec U_g^R$, then the degree of these risks can be ranked by risk utility value, the sequence being $R \succ Q \succ P \succ O \succ S$. Thus, the concept of ranking can provide negotiators knowledge about the risk factors and find the critical risk event.

(b) Critical risk and the general risk event

Based on the ranking mentioned above, the negotiators can know the maximum and minimum degree risk utility of O, P, Q, R, and S risk events. It can be easily found that risk event R is the most critical and risk event S is least critical in this case. The problem is that it is hard to find the critical risk events when there exist many risk events. We use the expected value to deal with the problem and find the critical risk event.
Suppose for the group negotiation with g negotiators of government $g = 1,2,\ldots,h$, there are $G-N$ risk events and N uncertain events. Let $f_G^g(w)$ denote the weight value of g negotiators. The weight value represents the different influence among the g negotiators. Since the g negotiators' utility is assumed to be dependent, the weight value will be 1, $f_g^G(w)=1$. Assume the government pursues the maximum utility, that is said, the government party pursues more uncertainty events. The level of optimal risk utility can be obtained by differentiation in U_g^G, the result is expressed as Eq. (16).

$$Max(E(U_g^G)) = Max(\sum_{G=1}^{G-N} f_g^G(w_g)U_g^G)$$

$$\frac{\partial(E(U_g^G))}{\partial U_g^G} = \frac{\partial(\sum_{G=1}^{G-N} f_g^G(w_g)U_g^G)}{\partial U_g^G} = \frac{\partial(E(U_g^G - \overline{U}_g^G + \overline{U}_g^G)}{\partial U_g^G}$$

$$= [\frac{\partial(E(U_g^G - \overline{U}_g^G))}{\partial U_g^G} + \frac{\partial(E(\overline{U}_g^G))}{\partial U_g^G}] \qquad (16)$$

$$Let \frac{\partial(E(U_g^G - \overline{U}_g^G)}{\partial U_g^G} = 0, \Rightarrow E(U_g^G - \overline{U}_g^G) = 0$$

$$\therefore E(U_g^G) = \overline{U}_g^G$$

where U_g^G is the total risk utility of the risk events for the government.

The result implies that the optimal risk level is the expected utility value of all risk events, $E(U_g^G) = \overline{U}_g^G$. Then, the critical risk event and general risk event can be found, the risk event is a critical event if $U_g^G > E(U_g^G)$. It is a general risk event if $U_g^G \le E(U_g^G)$, $\exists U_g^G \in \Omega_R^{G-N}$, for all $G = 1,2,\ldots,t$. Therefore, the critical risk event and general risk event can be defined in Eqs. (17) and (18), respectively.

(i). Critical risk event definition
Let $C.R.$ denote the set of critical risk events. For a specific r risk event, $\forall r \in G-N$, if the r risk utility is greater than $\overline{U}_g^{G-N}$, then the r risk event becomes a critical risk event. It can be expressed as Eq. (17).

$$\exists U_g^{G-N} \in \Omega_R^{G-N}, s.t. C R \equiv \{U_g^{G-N} > \overline{U}_g^{G-N}, \forall G-N = 1,2,\ldots t\} \qquad (17)$$

(ii). General risk event definition
Based on the concept in Eq. (17), the general risk event can be expressed as Eq. (18).

$$\exists U_g^{G-N} \in \Omega_R^{G-N}, s.t. C\dot{R} \equiv \{U_g^{G-N} \leq \overline{U}_g^{G-N}, \forall G-N=1,2,...t\} \tag{18}$$

The result of the critical risk event can be found by using Eq. (17) and the critical risk events should become critical bargaining chips during negotiation between the BOT concession company and government. Because the utility of general risk is not greater than the utility of critical risk events, these will be secondary in negotiation.

5. CONCLUSION

This paper has constructed a risk measurement model and risk analysis framework based on the multi-attribute decision making and utility theorems The risk utility function has considered a single attribute and multiattribute event, preference of individual negotiators, and the preference of group negotiators. This model can be used to measure risk, rank risk, and to find the critical risk event for the BOT concession company and government agency. Also, we have modified Jia and Dyer's (1996) definition of risk, which did not consider the factors of stability in risk.

Suppose the negotiator utility and events are both independent, the optimal risk level will then be the expected risk utility value of all events and be able to distinguish the critical risk events and general risk events. Accordingly, preference of utility, the critical risk event and general risk event can be obtained from the risk sets' optimal risk level, and it can be interpreted that critical risk events are the primary bargaining chips and general risk events are the secondary target of bargaining.

This study was conducted under the assumption that events, event attributes and utility functions of the negotiators are independent. In practical situations, however, events are not entirely independent and other negotiators will affect utility preference and cognition of the negotiators. The results will change when the assumptions are changed and we believe that this can be investigated in the future. Also, the game model of the negotiation contract can be explored.

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