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THE APPLICATION OF UTILITY THEORY IN THE DECISION-MAKING PROCESS FOR INVESTING IN ADR INSURANCE

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ABSTRACT

Since most projects today operate on tight budgets, one way to ease the potential for variations from budget is to price Alternative Dispute Resolution (ADR) techniques as an insurance product, which allows the project participants to transfer the risk of incurring unexpected high ADR cost during construction phase to the insurance company. Despite this advantage, many factors are preventing project participants from investing in ADR insurance. For example, on an, expected value (EV) basis, self-insurance almost always appears financially better than insurance premiums because of the insurance company's underwriting expenses and profit target that are included in the premium charges. However, expected value calculations miss important effects of uncertainty on the participants. In this paper, we borrow utility theory and introduce subjective loss to represent the "risk-averse" attitude of project participants when facing uncertainty. A convex subjective loss function (SLF) is used to translate the impact of ADR costs into utility-equivalent terms. Then the expected subjective loss is translated back to an equivalent certain monetary loss. Comparison between this derived certain monetary loss and the loss from investing in ADR insurance shows that even with the expense and profit loading, there is still an opportunity for a mutually advantageous insurance policy. And this opportunity grows larger as the potential ADR cost increases. Also, a numerical example is presented to illustrate how to structure a subjective loss function for project participants. It is the authors' hope that this paper could help project participants answer the question in the decision-making process: would they rather try to budget for an unknown cost in a wide range, or pay for insurance and be certain?

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INTRODUCTION

In a construction project, project participants always face uncertainty about future dispute resolution cost. For example, the participants do not know at the outset whether and when a dispute will occur and how much it will cost. This uncertainty not only impedes efficient use of funds (because the participants would prudently hold funds in reserve against the contingency of a dispute), but also results in project participants' constant anxiety over what will happen in the future. One way to reduce uncertainty's negative influence over the project would be to structure and price Alternative Dispute Resolution (ADR) techniques as an insurance product, which would allow the transfer of the risk of incurring unexpected high ADR cost during construction phase from project participants to the insurance company, and thus maintain a stable dispute resolution expenditure stream. If the problem is viewed on an expected value (EV) basis, when a decision maker is facing the uncertainty about a possible random loss X, he/she would be willing to pay no more than the expected loss amount $E[X]$ in order to be relieved from the future loss (Bowers *et al* 1997). This basis generally makes insurance meaningless to the insureds from the point of expectations as the premium an insurance company charges as a return for bearing the risk is almost always going to be greater than the expected dispute resolution cost $E[X]$ (unless the insurance company and the insureds have different expectations about the number and cost of disputes) because the premium includes an expense loading to cover the underwriting expenses and target profit of the insurance company.

However, decision makers do not necessarily follow the simple and straightforward result that EV would predict. Other aspects such as the magnitudes of and attitudes towards possible outcomes may also impact on people's perceptions and thus influence the decisions. For example, as early as 1783, Bernoulli designed a scenario where individuals would not consider paying for the privilege of playing a game even with an infinitely large EV (Li 2003). This was later referred to as the St. Petersburg paradox, and it illuminated the wide gap that sometimes exists between the EV prescription and actual behavior. In the insurance industry, take life insurance for example, according to the 2003 US Mortality Table (National Vital Statistics Reports 2006), the probability of dying for a male aging between 39 to 40 is only 0.001847. However people still pay hundreds even thousands dollars of premium to purchase life insurance in order to prepare themselves for unexpected events. That is because different people have different attitudes toward risk under different conditions and most people and organizations are risk averse to some degree. Similarly in construction projects, assuming the likelihood of dispute occurrence is 0.1, an ADR implementation cost of $1,000 might be of little concern to the project participants who then might be unwilling to pay more than the expected loss ($100) to obtain insurance. However, a possible dispute resolution cost of $10,000,000 could be catastrophic to the project. In this case, project participants might be willing to pay a fixed insurance premium that is in excess of the mean expected value of the loss in exchange for shedding some uncertainty about the future (Pritchett *et al* 1996). Project participants attach a different value to the dispute resolution cost they might incur based on their degree of aversion to the risk they face during the course of the

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project. This value is similar to the concept of "utils" in utility theory, which will be explained in detail later.

In this paper, concepts from utility theory have been borrowed to indicate the "risk-averse" attitude of project participants and a subjective loss function (SLF) is used to translate the impact of ADR cost into utility-equivalent monetary terms. The result shows that even with the expense and profit loading, there is still an opportunity for a mutually advantageous insurance policy. Finally, a numerical example is presented to illustrate how to structure a subjective loss function for project participants and how to calculate the optimal premium based on the function.

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PROBLEM STATEMENT

Without loss of generality, the risk of incurring ADR implementation costs in any construction project can be mathematically represented by:

1) n, the total number of disputes occurring in the period from the notice to proceed (NTP) ($t = 0$), to the project completion ($t = T$ days, $m < T/30 < m+1$ months); $n = N_1, N_2,.., N_k$ with probability $q_1, q_2,.., q_k$ respectively, where N_1 is the minimum possible number of disputes and $N_1 \geq 0$, while N_k is the maximum number of possible disputes;
2) c_i, the amount of ADR cost for each dispute resolution process, where $i = 1, 2,\ldots, n$ represents the dispute number. For purposes of illustrating this paper, we assume that the cost of each dispute is independent from others and bears m possible outcomes for each dispute, c_1 (resolved at ADR1), c_2 (resolved at ADR2), …, c_m (go to litigation), with probability p_1 p_2, and p_m respectively where $j = 1, 2,\ldots, m$ is the resolution type and $\sum_{j=1}^{m} p_j = 1$;
3) For the ith dispute, define $x_{ij} = 1$ represents that the ith dispute is resolved with the jth resolution type, while $x_{ij} = 0$ otherwise. Thus $x_j = \sum_{i=1}^{n} x_{ij}$ represents the total number of disputes that are resolved with the jth resolution type, and follows a multinomial distribution $M(n, p_1\ p_2,\ldots, p_m)$, with the expected value $E(x_j) = n\ p_j$, where $j = 1, 2,\ldots, m$. Specifically, when $m = 2$, then x_j follows binomial distribution $B(n, p_1\ p_2)$.
4) Among all n disputes, there are a total of R different possible outcomes. For each outcome, there could be x_j disputes resolved with the jth ADR. Consequently, the total ADR implementation cost throughout the time horizon for the rth outcome is $C_r = \sum_{j=1}^{m} c_j x_j$ with a probability of $P_r = \prod_{j=1}^{m} p_j^{x_j}$, given a total of n disputes. And the number of outcome which bears the same total cost and probability is $\binom{n}{x_1 \cdots x_j \cdots x_m}$.

Then assume for a specific project, the expected number of disputes is $E(n)$, which also represents the frequency of dispute occurrence; and the expected average ADR cost per dispute is $E(c_i)$ which also represents the expected severity of dispute resolution cost. Then, according to previous work by the Song (2009b) and by drawing analogy from health insurance, the gross premium for the ADR insurance is:

$$P = E(C) = E_P(C) + \alpha \qquad \text{Eq. (1)}$$

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Where $E_P(C)$ is called pure premium in the case of not carrying the premium, while α is an expense loading factor to cover the expenses and the target profits of the insurance company (Song *et al* 2009a). Specifically, we have

$$
\begin{aligned}
E_P(C) &= \sum_{n=N_1}^{N_k} q_n \sum_{r=1}^{R} \binom{n}{x_1 \cdots x_j \cdots x_m} C_r P_r \\
&= \sum_{n=N_1}^{N_k} q_n \sum_{r=1}^{R} \binom{n}{x_1 \cdots x_j \cdots x_m} \sum_{j=1}^{m} c_j x_j \prod_{j=1}^{m} p_j^{x_j} \\
&= \sum_{n=N_1}^{N_k} q_n \sum_{j=1}^{m} c_j \left(\sum_{r=1}^{R} \binom{n}{x_1 \cdots x_j \cdots x_m} \prod_{j=1}^{m} p_j^{x_j} \right) x_j \qquad \text{Eq. (2)} \\
&= \sum_{n=N_1}^{N_k} q_n \sum_{j=1}^{m} c_j (n p_j) \\
&= \sum_{n=N_1}^{N_k} n q_n \sum_{j=1}^{m} c_j p_j \\
&= E(n) * E(c)
\end{aligned}
$$

is called pure premium in the case of not carrying the premium, while α is an expense loading factor to cover the expenses and the target profits of the insurance company. As mentioned before, as long as α is not zero, not purchasing is always going to look better than insurance on an expected value basis. However, for this case using expected value to make decisions ignores the range of possible values and does not capture risk attitudes where insurance might be an advantageous risk management method to transfer away this financially catastrophic outcome (Clemen 1997). For example, assume for a certain project, the expected total ADR implementation cost is $ 1,000,000, where the mean expected number is 20 and the average ADR cost per dispute is estimated to be $50,000. However, the actual number of disputes likely has a range of possible outcomes (e.g., from 5 to 50), and the average ADR cost also likely has a range (e.g., from $15,000 to $100,000) depending on the nature of the disputes that arise, the effectiveness of the ADR utilized and the maximum allowable time for each step on the contractually agreed project dispute resolution ladder (Song *et al* 2009a). Then the actual total cost may vary from $75,000 to $5,000,000. If using expected value, any insurance with premium higher than $ 1,000,000 is not favorable to project participants. However, to the insureds, if the negative prospect of the possibility of incurring an unexpected large ADR implementation cost as high as $5,000,000 is taken into consideration, then the interpretation may be different and there is a motivation for project participants to consider investing in ADR insurance, even with a premium cost greater than $1,000,000. In utility theory, the prospect of this negative impact is the "negative utility" project participants attach to a certain

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ADR cost, and it is not the expected loss value but the "subjective loss value" of a loss that plays an important role in project participants' decision making process regarding whether to invest in ADR insurance or not (Hoshiya *et al* 2004).

UTILITY THEORY IN ADR INSURANCE

Utility theory is an attempt to infer subjective value, or utility, from choices (Bell *et al* 1988, Keeney *et al* 1993, Norstad 2005). It has been developed to provide insights into decision making in the face of uncertainty (Bowers *et al* 1997). Generally a utility function *u (w)* is used to indicate the value or utility that project participants attach to a certain wealth of amount *w* (Bowers *et al* 1997). Different from the traditional positive definition of a utility function, "subjective loss" employed in this paper is quantified by a subjective loss function (SLF) to indicate the negative utility *u(c)* that project participants attach to a given loss amount of ADR cost *c* resulting from dispute resolution. Following the notation in the problem statement, we have the total expected subjective loss

$$E\big(u(C)\big) = \sum_{n=N_1}^{N_k} p_n SL_n$$

Where

$$SL_n = \sum_{r=1}^{R} \binom{n}{x_1 \cdots x_j \cdots x_m} p_r u(C_r) = \sum_{r=1}^{R} \left(\binom{n}{x_1 \cdots x_j \cdots x_m} \prod_{j=1}^{m} p_j^{x_j} u\left(\sum_{j=1}^{m} c_j x_j \right) \right) \quad \text{Eq. (3)}$$

is the expected subjective loss for a total of *n* disputes. Then from the viewpoint of the insured, the maximum acceptable gross premium *P* for assuming loss *C* is determined from:

$$u(P) = E\big(u(C)\big) \rightarrow P = u^{-1}\Big(E\big(u(C)\big)\Big) \quad \text{Eq. (4)}$$

The left hand side of the equation represents the situation where the project has ADR insurance thus all project participants need to pay is the premium; while the right hand side is the case without insurance, where project participants should bear all the loss. In each case, the participant views the undesirable financial outlay (either the certain premium or the uncertain ADR costs) subjectively (the function u). It is natural to assume that *u(c)* is an increasing function because "the more loss, the worse (more negative utility) it gets". As mentioned earlier, while an ADR implementation cost of $1,000 might be of little concern to the project participants, a possible dispute resolution cost of $10,000,000 could certainly be worthy of a second thought. In addition, however, each additional equal increment of loss results in a larger increment of associated negative utility – a loss of $2 million has more than twice as much negative utility as a loss of $1 million. This is the mirror image of the principle of decreasing marginal utility in economics; we could call it "increasing marginal negative utility" in this case, which is schematically illustrated in Figure 1.

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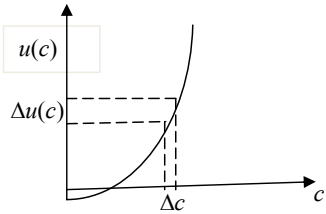

Figure 1 Example of Subjective Loss Function

The two properties suggested by Figure 1 are $u'(c) > 0$ and $u''(c) > 0$. The second inequality indicates that $u(c)$ is a strictly convex upward function.

According to Jensen's inequalities (Bowers *et al* 1997), for a random variable X and function $u(c)$ with a convex characteristic,

If $u''(c)>0$, then $E(u(X)) \geq u(E(X))$, vice versa.

In other words, project participants with SLF $u(c)$ are risk averse if, and only if, $u''(c) > 0$.

In Eq.(4) there is the expression of the maximum premium the risk-averse participant should be willing to pay:

$$u(P) = E(u(C))$$

Combining this with

$$E(u(C)) \geq u(E(C))$$

for a risk averse project participant, there should be an acceptable maximum premium:

$$P \geq E(C)$$

meaning that the participant is willing to pay an amount greater than the expected value of ADR cost for insurance to get rid of the risk of uncertainty.

HOW TO CONSTRUCT A SUBJECTIVE LOSS FUNCTION (SLF)

There is a simple step-by-step approach to establish project participants' SLF (Bowers *et al* 1997). First assign two utility values to two losses c_1 and c_2 (specifically $c_1 = 0$ to illustrate the situation where there is no loss). Then ask the question: assume that project participants are facing a loss of c_2 with specified probability p, what is the maximum amount G they would be willing to pay for complete insurance protection against this random loss to remain at the status of no loss ($c_1 = 0$) with probability 1-p? Expressing this in mathematical terms, the question is for project participants to fix a value G such that:

$$u(G) = \mathrm{E}[u(C)] = (1-p)*u(c_1) + p*u(c_2) \qquad \text{Eq. (5)}$$

Once the value $G=c_3$ is available, the point $[c_3, (1-p)*u(c_1)+p*u(c_2)]$ is determined as another point of the SLF. Following these steps, project participants could add as many points as necessary and with enough points a smooth function with a second

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derivative may be fitted to provide for a SLF that characterizes the risk-aversion of the participants.

For example, assuming for a project, there are two points on project participants' SLF, which we assign utilities of zero and one units of utility, respectively: $u(0) = 0$ *and* $u(20{,}000) = 1$. Suppose an ADR cost of $20,000 might be incurred with probability 0.5, or no ADR cost would be incurred with probability 0.5 (this is an oversimplified example to help explain the approach clearly. In reality there are more scenarios regarding ADR cost. An Event Tree Analysis (ETA) might be used to analyze the event of incurring ADR cost c_n with probability p_n). According Eq. (4), project participants are asked to determine the value G so that:

$$u(G) = 0.5*u(20{,}000) + 0.5*u(0) = 0.5.$$

Here if they pay G, then their loss will certainly remain at G, instead of the uncertain $20,000. The equal sign indicates that project participants are indifferent between paying G with certainty and accepting the expected subjective loss expressed on the right hand.

Assume the project participants decide that for them, $G = 12{,}000$. Therefore,

$$u(12{,}000) = 0.5$$

The result is plotted on the dash line in Figure 2. From it we can conclude that there is a possibility that participants would be willing to pay an amount for insurance (G = $12,000) that is greater than the expected value of the loss ($E(C) = 0.5*0+0.5*20{,}000$ = $10,000).

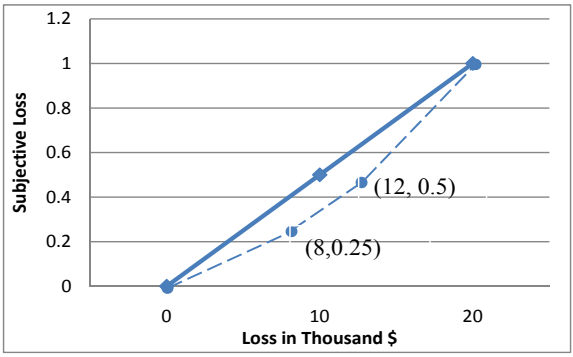

Figure 2 Determination of a SLF

The approximate SLF of Figure 2 consists of straight line segments with positive slopes. If we continue this process with the participants and obtain more points on the curve, we can generate a smooth curve which bears the properties of $u'(c)>0$ and $u''(c)>0$, as long as we are dealing with risk averse project participants.

Building project participants' SLF is a way to replace their qualitative preference from among alternatives that have uncertain payoffs with a consistent numerical comparison. As simple as the procedure appears, this could, however, turn out to be a rather complicated process. This is because the process is a matter of subjective

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judgment and depends on many factors such as conflicting attitudes toward risk among project participants, project type, and environment of financial market, etc. (Bowers *et al* 1997). Even for the same project participants, different projects will have different subjective loss functions, thus requires re-evaluation. In utility theory, there are several elementary functions that can be used as utility function such as exponential, fractional power, quadratic functions, to name a few (Bowers *et al* 1997). In this paper, quadratic function (as in Eq.(6)) is adopted as project participants' SLF due to three reasons. First, it bears the properties necessary to represent a risk-averse attitude. Second, it is the closest function form which can be used to estimate our pilot data. Last but not the least, it is one of the fundamental functions and is easy to comprehend and calculate.

$$u(x) = ax^2 + bx + c \qquad a, b > 0, x > 0 \qquad \text{Eq. (5)}$$

Using the approach described above, the values of constant a, b, and c could be estimated using regression. To elaborate, first a financial survey should be conducted for project participants to show their different perception of a given series of loss values. Then with several points plotted on the SLF line, the regression of the actual loss values and the impact of those losses (valued by project participants in comparison to previous established utility values) would be the subjective loss function. An illustrative example is presented in the next section to explain how can we calculate the subjective loss and its corresponding monetary term.

IILUSTRATIVE EXAMPLE

Assume there is a highway bridge project where project participants decide to include a three-stepped DRL in the contract for dispute resolution. In this DRL, a dispute goes through Architect/Engineer or Supervising Officer (ADR1) to mediation (ADR2), then arbitration (ADR3) if the first two fail to provide a satisfactory settlement. More specifically, when the dispute resolution process starts, the dispute is first turned to Architect/Engineer or Supervising Officer. To calculate this expense, assume for this illustrative calculation that the unit cost is $500 per day for this step. If the initial attempt fails to achieve the settlement within the maximum allowable time of d_1 = 60 days, the dispute escalates to the next level with mediation between the owner and contractor representative; assume the cost at this level is at a unit cost of $1,500 per day and d_2 = 30 days. Finally, if the dispute is not resolved at the previous levels, it is turned to the final step of arbitration. Assume for this illustration that the cost at this level is $3,000 per day with d_3 = 60 days. Assume that the estimated duration of this project is T=1,450 days after NTP (assume there are 30 days in each month, $m = 48 < T < m+1 = 49$).

For illustration purpose, we make the following simplified assumptions. Based on statistical data and past experiences on similar projects, the owner estimates that

1) The above DRL will be required to resolve a total of 1, 2 or 3 potential disputes resulting from different dimensions of the project with a probability of 25%, 50%, and 25% respectively.

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2) Each dispute will cost on average \$63,850 with two possible outcomes: a) for a probability of p = 98% it will stay on the DRL and cost $c1$=\$27,500; and b) for a probability of (1-p) = 2% it will escalate to litigation and cost $c2$= \$1,845,000 (with expected value equals to the average cost \$63,850).

Based on our assumptions, when there are n potential disputes, there will be potentially n+1 outcomes for total ADR implementation cost: 0, 1, 2,…, n ADR resolutions (or n, n-1, n-2, …,0 litigation resolutions). The number of ADR resolutions follows Binomial distribution $B(n,p)$.

According to Song *et al* (2009a), the estimated pure premium (PP) is:

$$PP = E(n) \cdot E(c_i) = 2 \times \$63{,}850 = \$127{,}700$$

Add an Expense Loading Factor (ELF) of 35% (illustrative value, including a provision for profit, assumed for this example), the Gross Premium (GP) should be:

$$GP = \frac{PP}{1 - ELF} = \frac{\$127{,}700}{1 - 35\%} = \$196{,}462$$

Follow Eq. (4) and ask project participants to attach their perceptions to develop equivalences to a series of loss values in utility terms. Then, fit a Polynomial Regression to the paired responses to estimate the participants' subjective loss functions. As shown in Figure 3, the regressed function is:

$$u(x) = 0.00003 * x^2 + 0.8 * x$$

Because $u'(c)>0$ and $u''(c)>0$, this function meets the requirements for risk-averse project participants .

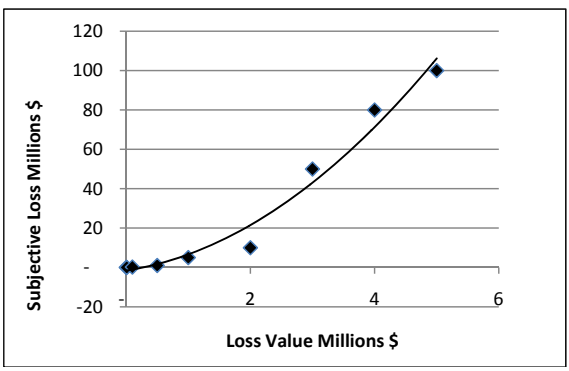

Figure 3 Subjective Loss Function for project participants

To determine the SLF of project participants, we calculate the SL_n for each possible number of disputes over the time horizon. Eq.(3) is simplified to

$$SL_n = \sum_{r=0}^{n} \binom{n}{r} p^r (1-p)^{n-r} u(rc1 + (n-r)c2) \qquad \text{Eq. (6)}$$

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When n=1, we have two possible outcomes, either the only dispute is resolved with ADR or with litigation with probability p and 1-p respectively. Then,

$$SL_1 = pu(c1) + (1-p)u(c2) = 2{,}115{,}730$$

When n=2, we have three possible outcomes for the time horizon: zero ADR, one ADR, or two ADR resolutions. Then,

$$SL_2 = (1-p)^2u(2c2) + 2p(1-p)u(c1+c2) + p^2u(2c1) = 4{,}476{,}066$$

When n=3, we have four possible outcomes for the time horizon: zero ADR, one ADR, two ADR, or three ADR resolutions. Then,

$$SL_3 = (1-p)^3u(3c2) + 3p(1-p)^2u(c1+2c2) + 3p^2(1-p)u(2c1+c2) + p^3u(3c1) = 7{,}081{,}014$$

Thus the total subjective loss

$$E\big(u(C)\big) = \sum_{n=1}^{3} p_n SL_n = 4{,}537{,}219$$

According to Eq.(4), to make insurance attractive to a participant, there should be a maximum amount of money P^* which satisfies $u(P^*) \leq E[u(C)]$ or

$$P^* \leq u^{-1}(E[u(C)]) = \$375{,}792$$

The results are summarized in Table 1. From the Expected Value perspective, project participants are willing to pay up to \$127,700 for certain to shirk the risk of uncertainty. To assume the same amount of risk, the insurance company charges a gross premium of \$196,461. In this case, insurance is never an attractive option because neither the project participants will pay more to invest in insurance nor the insurance company lower its premium. From the subjective loss perspective, however, risk-averse project participants are willing to pay up to \$375,792 for certain to shirk the risk of unusually large ADR expense. Their maximum acceptable certain loss is much higher than the premium charged by the insurance company. Consequently, investing in insurance becomes much more attractive.

Table 1 Loss value for the project participant

	Project participant perspective	
Loss valuation basis	Without insurance	With insurance
Expected value basis	\$127,700	\$196,461
Subjective loss basis	\$375,792	\$196,461

CONCLUSION

This paper investigated the application of utility theory in the decision-making process for project participants to invest in ADR insurance. We first introduced the concepts of subjective loss, and then explained how subjective loss can better represent risk-averse project participants in evaluating uncertainty, thus providing a possible explanation for the validity of third-party insurance in construction management. Our study shows that despite insurance company's additional expense

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underwriting and profit loading, there may still exist the opportunity for a mutually advantageous ADR insurance. This ADR insurance, while not a tool to eliminate the possibility of a possible dispute resolution cost, is a powerful alternative in risk management to transfer the financial risk to a third party.

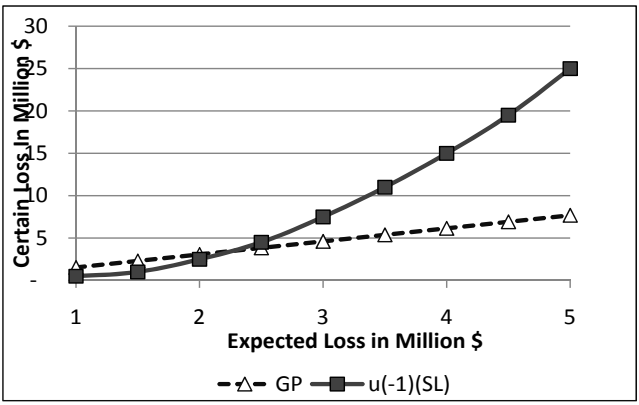

Figure 4 Expected Payouts for Project Participants (Simplified example for illustration)

We also conclude that a Subjective Loss Function could be constructed to indicate the "risk-averse" attitude of project participants and quantify the impact of ADR cost in utility terms. As shown in Figure 4, when the expected loss for risk-averse project participants is low, their maximum acceptable certain loss based on subjective loss perspective could be lower than the gross premium by the insurance company. However, as the expected loss increases, this maximum acceptable certain loss increases at a higher ratio then the gross premium. After a certain point, investing in insurance becomes an attractive option for the project participants. Future research could focus on how to determine the range of premiums acceptable to both project participants and the insurance company.

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