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THE USE OF RELIABILITY ANALYSIS IN BID DECISION-MAKING PROCESS

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Abstract: In general, contractors prepare bid offers within a short and limited time, when they rely on their experience and intuition. In this process, a wide range of factors may have an impact on the bid pricing risk. Of these, the client's reputation or the record of the projects owned by the client may entail vital contribution on the issue. This study develops a practical quantitative approach which enables estimators to process the bid risk allocation in an easy and rapid manner. Through reliability analysis, the developed method enables practitioners to make informed bid/no-bid decisions based on estimating the probability of the cost overrun. The cost overrun probability distribution is adopted to estimate the expected value of such variable. The practicability of this proposed method is tested against empirical data obtained from 40 university construction projects. The contribution of this study is to provide a simple, rapid and cost-effective method applicable in bid decision-making processes.

1 INTRODUCTION

Contractors worldwide face the challenging task of bid-decision making and offering a bid price high enough to generate a decent profit and low enough to win the bid (Asgari et al. 2016). This process involves several steps of preparing quantity take-off, cost estimation, risk allocation, bid preparation, price negotiation and reaching an agreement. Moreover, the final decision regarding a project is heavily influenced by assumptions on uncertainties of the projects (Duzkale and Lucko 2016).

Depending on the nature of the project, contractors typically consider a risk margin of 1-10 % of the estimated cost intuitively (Laryea and Hughes 2011). Moreover, the entire bid-decision making process is typically required to be completed subject to tight scheduling, over a short period of time, when collecting the necessary data is very difficult (Ballesteros-Pérez et al. 2013). Consequently, relying on past experiences and intuition is very common in such decision making process (Laryea and Hughes 2011).

There exist studies on bid risk assessment process where, the proposed analytical models are too complicated for estimators and managers (Laryea and Hughes 2011). These methods require massive data inputs and advanced mathematical apparatus making the construction practitioners reluctant to practically apply them. There is a need to develop a practical bid risk assessment model that would overcome those drawbacks. Common bid-decision making practices lack reliability, accuracy and this exposes the contractors to a wide range of damaging consequences.

The primary objective of this study is to propose a systematic and accurate bid decision-making framework with applicable risks, understandable and practical for contractors. In addition to adding value to the exiting body of knowledge on bid decision-making, the findings here will be of direct appeal to construction practitioners, estimators and planners.

2 Background

2.1 Bid Decision Making Process

Construction companies typically survive and expand their business volume through successful bidding on available projects. Due to its importance, since 1950, a rich body of literature is devoted to assess various features associated with contractors' bid-decision making practices (Chou et al. 2013). Bid-decision making process for contractors encompasses two overlapping stages of deciding whether to bid or not and if yes then calculate the bidding price (Awwad 2016). These two overlapping stages are interrelated with bidding price calculation as a highly influential factor in making bid/no-bid decision, where bidding price defines expected profit and the company's position in terms of competition. The bidding price makes it clear whether the contractor has the ability and resources to carry out such a project. Calculating the bidding price for contractors typically is of two phases: estimating the actual project costs and adjudication, that is, applying market conditions. The estimated cost of the project is derived from tender documents and drawings by calculating the quantities and the corresponding costs of required project resources (material, labor, machinery, etc.). Evidence indicates that cost estimations might be somewhat inaccurate due to the time pressure factor accompanied with ambiguity and lack of details in tender documents (Laryea and Hughes 2011).

The process of bid decision making is very risky and full of uncertainties and requires close consideration of current market state of affairs, competitiveness level, information of opponents and financial circumstances of the company; hence, a very complex and multidimensional decision making process (Awwad 2016). These parameters make the importance of accurate incorporation of risks and uncertainties in bidding pricing processes outstanding.

2.2 Reliability Analysis

The reliability analysis has emerged to provide information in decision-making processes in practice, where a certain amount of known and unknown risks are involved (Singh et al. 2007). The objective of reliability analysis is to quantify the probability of failure of the system and its protective barriers. Reliability analysis, as a practical decision-making technique, reflects on the state of knowledge for the treatment of uncertainties in risk assessments. This method has become one of the most common techniques in quantifying risks and an effective tool to provide an image of a complex system's likely behavior affected by a wide range of factors and uncertainties. The reliability analysis method is based on the limit state function defined through Equation (1). Where, Q is the statistical variable representing external forces or demands and R is the resistance (capacity, or supply). In this method the safety margin of the system is described by the reliability index β, as defined in Equations (2 and 3).

$$g = R - Q \tag{1}$$

$$\beta = -\Phi^{-1}(P_F) \tag{2}$$

$$P_F = P(g < 0) \tag{3}$$

P_F is the probability of system failure and Φ^{-1} is the cumulative standard normal distribution function inverse; thus, the probability of failure is presented as Equation (4)

$$P_F = \Phi\,(-\beta) \tag{4}$$

Reliability is defined as the probability of no failure where failure is associated with intended objectives of a decision making process. In the contractors' context the project is failed when it faces cost or schedule overruns, hence a failure in meeting the desired objectives of the contractor and the owner/client. With reference to Equation (1), *Q* is the cost or time where the project is actually accomplished and *R* represents the agreed cost or time mentioned in the contract or bid. This perspective provides estimators and managers with a new approach to manage bid decision-making based on estimating the probabilities of schedule and cost overruns with respect to records of the accomplished projects (Galway 2004). Bidding price is significantly affected by the owner's reputable record regarding past projects (Ye et al. 2014). Such a record reflects the financial condition of the owner, likelihood of obtaining a guarantee of payment, and the level of the bid bond all effective in calculating the cost. Irregular payments, frequent change orders and delayed decision-making by the owners end up in lower performance and higher costs in carrying out projects (Ghoddousi and Hosseini 2012). In this study, owner's records are conceptualized in a probabilistic form of project cost failure (overrun) obtained from the past projects to facilitate contractors in quantifying the level of the risk associated with this factor. The probability of cost overrun can be estimated through the best-fit probability distribution functions (PDF) for actual and estimated cost for project completion.

3 Methodology

Within the context of reliability analysis, the probability of failure is shown shaded in Figure 1. With reference to Equation (1), where, *Q* and *R* are normally distributed, the reliability index β is estimated through Equation (5), where the symbol μ is the mean and σ is the corresponding standard deviation of the normal variables. In some practical cases *Q* and/or *R* deviate from a normal distribution. In such cases, the Rackwitz-Fiessler iterative technique can be applied in estimating β based on the normal transformation of non-normal distributions (Ghodoosi et al. 2015 and 2016). The Rackwitz-Fiessler iterative method is adopted to estimate the reliability index and the corresponding probability of project failure in this study.

$$\beta = \frac{\mu_R^e - \mu_Q^e}{\sqrt{{\sigma_R^e}^2 + {\sigma_Q^e}^2}} \tag{5}$$

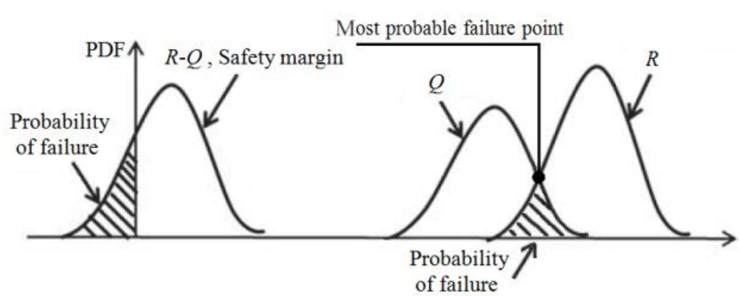


Figure 1: PDFs of Q and R and the probability of failure (adapted from Nowak and Collins, 2000)

After the reliability index is calculated, the probability of cost failure for a new project owned by the client is estimated as $P_F = \Phi\ (-\beta)$, as defined in Equation (4). Contractor is usually responsible for the majority of risks involved in construction like quality problems, losses and delays due to improper means and methods of construction, poor productivity, labor strikes, construction plan changes and poor site safety. Owner's reputation in the form of project failure probability obtained from the past projects assists construction managers decide whether to take such big responsibility and bid for a new project, avoid bidding by a no-bid decision, or adjust their bid pricing accordingly.

In this study the dataset covers the actual/contract cost for 40 projects with the University of Isfahan (Iran) as the client. These were selected from a bigger statistical population where the contractor selection processes and contract type are almost identical. All contracts were subject to open competitive tendering. In addition, the project size, original contract cost and the contract period for all 40 selected projects are in similar ranges, that is, applicable in small to medium contracts.

Upon collecting the data, the best-fit probability distribution is estimated for each set of cost data, Figure 2. The Oracle Crystal Ball 11.1.1 as described by Ghodoosi et al. (2015 and 2016) is applied to determine the best-fit cost and schedule distributions. Next, the iterative Rackwits-Fiessler reliability analysis is run on the actual and contract probability distributions and the reliability index is estimated accordingly. The probability of cost failure for a new project owned by the client is estimated through Equation (4).

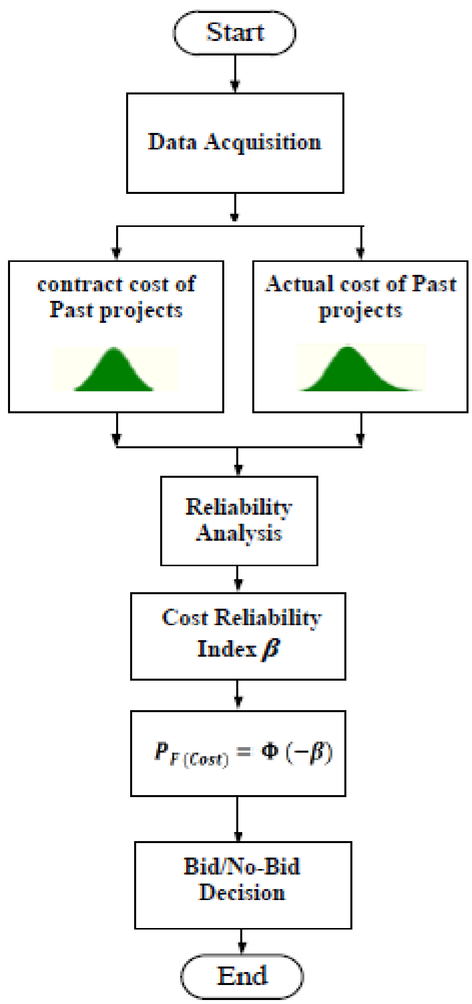


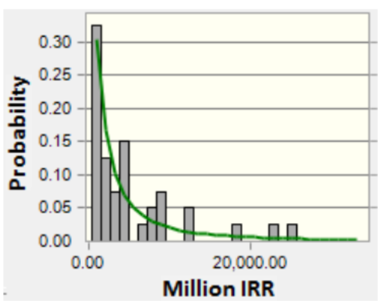
Figure 2. Bid/No-Bid decision making based on reliability analysis

With respect to contractor's responsibilities regarding the majority of construction risks, company's financial and logistic situation and the owner's record in form of probability of project failure (P_F), a contractor may decide to avoid bidding (no-bid decision), try to negotiate with the owner or adjust the bid pricing accordingly. This newly proposed process is straightforward, easy and rapid as compared to the existing analytical approaches available in the related literature.

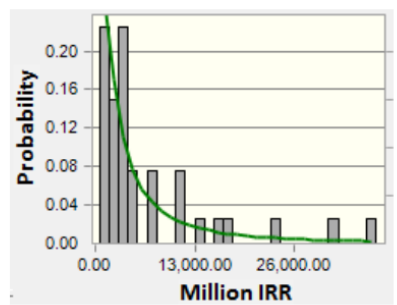
4 From Data to Findings

The cost of risk is modeled as probability of cost failure multiplied by the impact thereof. Cost overrun is defined as the difference between a project's contract (bid) price and the actual construction cost. By subtracting the actual cost from the contract cost for the past projects owned by the client, a set of cost overrun data is yield. The best fit continues PDF to the cost overrun, $f_x(x)$, is estimated through Oracle Crystal Ball 11.1.1.

As a case study, the best fit distributions to the actual and contract cost and schedule for 40 case-study projects are estimated trough Oracle Crystal Ball 11.1.1, Figure 3. As discussed, normal approximation of the non-normal cost distributions are estimated according to the Rackwitz-Fiessler iterative method. The reliability index and the corresponding probability of cost failure (overrun) are calculated according to Table 1. The obtained results indicate that the probability of cost overrun for the projects is 49%. This information assigns a value to the record of client/owner in terms of the financial ability, payment record, decision-making capabilities, number of change orders and contract administration competency.



(a) Best fit distribution for contract cost, lognormal with μ =8507.17, σ =2496 and γ =325.99



(b) Best fit distribution for actual cost, lognormal with μ =8972.48, σ =2173 and γ =325.02

Figure 3: The best fit probability distributions for actual and contract cost and time (IRR: Iranian rial, μ: Mean, σ: Standard deviation,US$/IRR was close to 32400 in 2016)

Table 1: Reliability index and probability of cost overrun for 40 case-study projects

Failure	Reliability index β	Probability of failure $P_F = \Phi\,(-\beta)$
Project Cost	0.026	0.49

Managers should decide whether to bid for a project based on this newly proposed quantified owner's reputation. It is important to note that many parameters may influence cost overrun; however, by considering many projects of matching size, contract type, client sector and contractor selection process, the client's performance and reputation becomes essential. In case the contractor decides to bid for a new project, the cost of risk can be estimated using such estimated probability of failure.

Provided that the contractor decides to accept such level of client/owner's failure rate (49%), the cost of risk is calculated based on the contractor's risk aversion and market competition. In order to estimate the bid price for a low-rise building located in the region under study with the same owner/client associated with the previous 40 projects (source of data), different cost overrun ranges could be estimated. Contractor decides the level of acceptable risk for the company and directly calculates the cost of such risk.

Based on this developed model and the records of the previous projects owned by the client, contractor is able to quantify the owner's reputation. For instance, for the above mentioned client contractor may consider several scenarios. Frist, taking into account the very high rate of cost overrun, contractor may avoid bidding for a new project with such client. Second, to be in the safe side, contractor may add up to 49% to the preliminary cost estimation and may bid for a new project; if the proposed bid is not won the contractor would have a rational justification. Finally, contractor realises the high risk of working with such client and tries to apply negotiation techniques and construction technology modifications to minimize the costs as much as possible. In the case where the client is found to be reputable with a low probability of cost overrun, contractors are more flexible to lower the risk element of markup with confident.

Although discussed in brief, the process and approach proposed here will be of direct appeal to construction companies and estimators involved in bidding decision-making. That is, when bidding for a new project, a contractor should consider its financial situation, current workload of the company, market situation and managers' risk aversion. Accordingly, many factors affect the decision making process, leaving decision makers with a multifaceted complicated matter of concern (Awwad 2016). The methodology proposed here simplifies the problem for contractors. That is, client/owner record is treated as a reflector of what happened in the past projects to quantify the risks associated in working with this client/owner. Through a simple calculation, construction companies can avoid losing money on complicated bid/no-bid decision making procedures, something evident in current practice in the construction industry (Hwang and Kim 2016).

This study provides a background for addressing the problems of 'overcomplicated existing solutions', 'lack of data' and 'tight scheduling' for bid pricing. According to the proposals of this study, based on the data acquired from the past projects and running reliability analysis, the probability of cost overrun is calculated simply as quantitative values. This gives practitioners an insight as to the potential of failure and informs subsequent steps in the bid decision-making process.

When a contractor is confident that the lowest possible price is proposed, if the proposed bid is not won the contractor would have a rational justification. Besides, the outcome directs contractors towards implementing the best options available to encounter the potential failure rate.

5 Conclusions

This study stands out among of its kind in several manners: first, existing analytical models are found to be too data-driven, time consuming and complicated for estimators and managers; second, the existing models do not address the actual risk allocation process applied by the contractors during the tender preparation. These facts indicate that the main benefit of applying this developed method in the bid decision making process is its being easy, rapid and applicable by practitioners who are trained with the basics of probability and statistics. The developed risk analysis model is dynamic by nature, that is, it can be applied to any type of project where different levels of risk and probability of failure are involved. Moreover, this newly proposed method is flexible in terms of project size, original contract cost and the contract period.

In theoretical sense, this developed method offers a new procedure for allocating the cost overrun risks to bid decision-making process where reliability analysis and theory of probability and statistics are applied.

This innovative combination would assist managers in bid/ no-bid decision and estimating a reasonable competitive bid price where client's record and financial ability, record of projects owned by the client, format of the contract and tender documents, payment regularity, scope of work, competition and contractors' technical capability are of concern.

Applicability of this method is affected by the lack of access to clients/owners' records in more detail. The reasons might be issues of classification, proprietary practices, and sensitivity to retrospective critical review of project management decisions. More quantitative studies are required in this area in order to convince the industry regarding the necessity and usefulness of such risk evaluation techniques.

It is recommended here that a more comprehensive model with the correlation between time and schedule overruns be developed. Also, this developed model can be combined with the existing probabilistic models which consider the historical bidding experience or patterns of competitors (Crowley 2000). Such combination could be a powerful tool that can support more objective bid decision makings.

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