A DECISION SUPPORT TOOL FOR CONTINGENCY AND PROFIT ANALYSIS OF INTERNATIONAL CONSTRUCTION PORTFOLIOS

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ABSTRACT

A DECISION SUPPORT TOOL FOR CONTINGENCY AND PROFIT ANALYSIS OF INTERNATIONAL CONSTRUCTION PORTFOLIOS

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In construction sector, estimations of contingency and profit amounts are generally based on experience and intuition. However, the relation between the desired profit amount and the risk undertaken is not considered usually during profit setting. In addition, most of the studies in the literature have been focused on a single project's contingency rate, but many construction companies carry out several projects simultaneously. Contingency-profit analysis for portfolios of projects is very important to evaluate the adequacy of the expected profit in terms of the risks undertaken for construction companies. This study aims to fill the mentioned gaps in contingency-profit evaluation for portfolios of international construction projects by developing a decision support tool. The developed tool estimates portfolio contingency rates by using

a method that integrates regression analysis and bootstrap method, and this method includes the advantages of parametric and probabilistic estimating methods at the same time. The proposed tool will show the condition of portfolio on the risk-profit evaluation graph. In this way, the tool enables companies to decide on sufficiency of the expected profit rate in response to the undertaken risks. Moreover, the decision support tool provides a contingency range for the planned portfolio, and the obtained range enables contractors to evaluate their portfolios in different cases.

In this thesis, the presented tool for contingency and profit analysis of international construction portfolios is introduced using a sample portfolio that consists of international construction projects. The developed decision support tool enables contractors to perform overall risk return analysis of their portfolio to achieve adequate contingency and profit decisions during bidding for international projects.

Key Words: Portfolio Contingency-Profit Analysis, Contingency Estimation, Regression Analysis, Bootstrap Method

ÖZ

ULUSLARARASI İNŞAAT PORTFÖYLERİNİN RİSK PRİMİ VE KÂR ANALİZİ İÇİN KARAR DESTEK ARACI

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İnşaat sektöründe, risk primi ve kâr miktarlarının tahminleri genellikle tecrübe ve sezgilere dayanır. Ancak, kâr belirleme esnasında, istenen kâr miktarı ile alınan risk arasındaki bağlantı çoğunlukla düşünülmez. Ayrıca, literatürdeki çalışmaların çoğu tek bir projenin risk primi oranına odaklanmıştır, fakat birçok inşaat firması aynı anda birkaç proje yürütmektedir. İnşaat firmaları için, projelerden oluşan portföyler için risk primi-kâr analizi, alınan risklere göre beklenen kârın yeterliliğini değerlendirmek için çok önemlidir. Bu çalışma, bir karar destek aracı geliştirerek uluslararası inşaat projelerinden oluşan portföyler için risk primi-kâr değerlendirmesindeki bahsedilen eksiklikleri gidermeyi amaçlamaktadır. Geliştirilen araç, regresyon analizini ve bootstrap

yöntemini birleştiren bir yöntem kullanarak portföy risk primi oranlarını hesaplamaktadır ve bu yöntem, parametrik ve olasılıksal hesaplama yöntemlerinin avantajlarını aynı anda içermektedir. Önerilen araç, portföyün durumunu risk-kâr değerlendirme grafiğinde gösterecektir. Bu şekilde, araç firmalara alınan risklere karşılık olarak beklenen kâr oranının uygunluğuna karar verme imkanı tanımaktadır. Ayrıca, karar destek aracı planlanan portföy için risk primi aralığı bulmaktadır ve elde edilen bu aralık, müteahhitlere farklı durumlarda portföylerini değerlendirmeleri için olanak sağlamaktadır.

Bu tezde, uluslararası inşaat portföylerinin risk primi ve kâr analizi için takdim edilen araç, uluslararası inşaat projelerinden oluşan bir örnek portföy kullanılarak gösterilmiştir. Geliştirilen karar destek aracı, uluslararası projelere teklif verme esnasında müteahhitlere, yeterli risk primi ve kâr kararlarına erişebilmek için portföylerinin kapsamlı risk ve gelir analizini yapma olanağı sağlamaktadır.

Anahtar Kelimeler: Portföy Risk Primi-Kâr Analizi, Risk Primi Tahmini, Regresyon Analizi, Bootstrap Yöntemi

TO MY FAMILY

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ANN	Artificial Neural Network
CPI	Contingency Performance Indicator
CRR	Country Risk Rating
ECPD	Empirical Cumulative Probability Distribution
e.g.	“exempli gratia” in Latin, and means “for example” in English
EMV	Expected Monetary Value
ERA	Estimating Using Risk Analysis
ICRG	International Country Risk Guide
MAPE	Mean Absolute Percentage Error
MPT	Modern Portfolio Theory
OFD	Office of Facilities Development
PERT	Program Evaluation and Review Technique
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
SPSS	Statistical Package for the Social Sciences
SSR	Sum of Squared Residuals
UFC	Unified Facilities Criteria

USD	United State Dollar
VBA	Visual Basic for Applications

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction companies have limited resources to assess risks and determine a contingency rate for international construction portfolios of projects, and they encounter with unique risks in universal markets in addition to ordinary risks faced in domestic markets. Moreover, international projects contain more risks and tend to have a high possibility of financial loss (Han, Kim, Kim, & Jang, 2008). Identifying possible risks in projects is very crucial to succeed in project management and make a profit on international projects.

Contingency amounts are used to cover costs resulting from project risks. Using an efficient contingency amount is very important to be successful in the international markets (Sonmez, Ergin, & Birgonul, 2007). Determination of a proper contingency amount is necessary for preventing cost overrun and holding the chance of winning the tender.

Selection of suitable contingency and profit rates can be achieved by understanding relationship between risk and return. Markowitz (1952) represented the mathematical formulation of risk-return relationship in his Modern Portfolio Theory (MPT). Being inspired by the concept of efficient frontier in MPT, a new concept named normal contingency-profit curve is proposed in this study. The proposed concept will help investors and contractors to evaluate their portfolios in terms of contingency-profit relationship.

1.2 The Purpose of the Study

Probabilistic and statistical methods for risk quantification and contingency determination have been developed in recent years; however, several empirical studies have shown that these methods are rarely used in practice. Many contractors do not use analytical methods to determine contingency amount in order not to become noncompetitive during bidding stage (Laryea & Hughes, 2011). Contractors' approach to profit determination is similar to contingency determination. Commonwealth of Massachusetts Division of Capital Asset Management points out in their Consultants Estimating Manual (2006) that that past data adjusted by a detailed understanding of marketing conditions likely to affect the current project must be used to obtain a proper profit percentage (p.10). In other words, it is very common that contingency and profit amounts are traditionally estimated as a predetermined percentage of project base cost.

As mentioned above, estimations of contingency and profit ratios are generally based on experience and intuition; therefore, estimated contingency and profit ratios can not be evaluated in terms of efficiency and closeness to the experimental trends by companies during bidding stage. In addition, most of the studies have been focused on a single project's contingency rate, but many construction companies carry out several projects simultaneously. In construction sector, there is a necessity for studies to perform portfolio contingency-profit analysis. This study aims to fill the mentioned gaps in contingency-profit evaluation for portfolios of international construction projects by developing a decision support tool. The purpose of the decision support tool is to eliminate lack of measurement for portfolio contingency and profit ratios. The decision support tool will help contractors and investors to perform a risk-return analysis for their portfolios of projects, and users can evaluate their portfolios in terms of risk-profit relationship by the help of proposed regions in the analysis. The developed tool will also show how far estimated contingency and profit ratios are away from the experimental trend line of the contingency-profit relationship. In addition, the tool provides range estimation for the portfolio contingency rate, and users have a chance to evaluate their portfolios at different cases.

1.3 The Scope of the Study

This study initially examines terms of risk, contingency, and profit. General definitions of these terms, risk assessment methods, and contingency determination methods are explained. Risk-return and contingency-profit relationships are also studied in order to master the subject.

Moreover, literature about modelling methodologies, which helps to understand how the decision support tool has been developed, is provided in this research. Concepts of efficient frontier, regression analysis, bootstrap method, and empirical cumulative probability distributions are investigated.

Furthermore, background of modelling is also explained in detail. Data of construction projects, which is used for contingency-profit analysis, is indicated. Determination of initial regression model is also clarified. In addition, fitting a contingency-profit curve to the historical data is examined, and a new concept named normal contingency-profit curve is proposed in this study.

The developed tool offers two choices that are entering actual project data into the project database and performing contingency-profit analysis for planned projects. The developed tool enables contractors and investors to expand the project database by entering data of completed projects. In addition, the tool performs a contingency-profit analysis for portfolios by using the registered data of projects in the project database, and four different regions are proposed to show condition of the portfolio in terms of risk-profit relationship. Further, the tool provides range estimation for portfolio contingency rate, and users can evaluate their portfolios at different cases.

The proposed tool is then illustrated using project portfolio of a Turkish contractor. Initially, data of 2 completed projects, which were carried out in Afghanistan and Turkmenistan, is entered into the project database. Later, the decision support tool is used for a sample portfolio that includes 2 international construction projects, which will be carried out in Turkmenistan and Iraq. As a result, the result of portfolio contingency-profit analysis is given, and the result of the model application is discussed.

CHAPTER 2

RISK, CONTINGENCY, AND PROFIT

2.1 Risk and Risk Management

The global construction industry is constantly changing, and it seems to become a more complex area including high risk. The increasing speed of development around the world results in raised uncertainty, and this issue makes every sector more risky. High risk and low profit rates have necessitated risk management to be successful in the international markets.

In this research, risk will be studied in terms of financial impacts on international construction projects. Understanding risk and risk management processes are helpful to comprehend the concept of contingency that is an output of risk management.

Project Management Institute (PMI, 2008) defines risk as an uncertain incident or situation that, if it occurs, may have negative or positive impacts on project objectives that comprise scope, schedule, cost, and quality. There are many different types of risk and classification of risks could be helpful to identify risks. Mulcahy (2013) states that there are many ways to divide risks into groups, and he chooses to categorize risks as follows:

- **External:** Regulatory, environmental, government, market shifts
- **Internal:** Time, cost, scope of changes, inexperience, poor planning, people, staffing, materials, equipment
- **Technical:** Changes in technology
- **Unforeseeable:** Only a small portion of risks (some say about 10 percent) are actually unforeseeable

Considering increasing impacts of risks on international construction projects, risk management is so crucial to be successful in structure projects. Risk management is defined as a methodical process of understanding, assessing, and controlling risks to raise the chances of objectives being accomplished (The Institute of Risk Management, n.d.). Risk management consists of some processes, and Mulcahy (2013) listed six sequential processes as indicated below:

1. Risk Management Plan
2. Identifying Risks
3. Performing Qualitative Risk Analysis
4. Performing Quantitative Risk Analysis
5. Planning Risk Responses
6. Controlling Risks

2.1.1 Risk Management Plan

Companies specify how risk management will be structured and performed for projects at this stage. Heldman (2009) indicates that the purpose of this step is to determine how risk management processes will be implemented and checked throughout the project duration. According to the Project Management Body of Knowledge Guide (PMBOK Guide, 2008), elements which should be included in the created risk management plan at this stage are: “methodology, roles and responsibilities, budgeting, timing, risk categories, definitions of risk probability and impact, probability and impact matrix, revised stakeholder tolerances, reporting formats, and tracking.”

2.1.2 Identifying Risks

There are multiple sources of risks and risks should be identified to be able to make analyzes. Risk identification is generally performed during project planning stage; however, some risks may be determined later in the project. Heldman (2009) listed risk identification techniques as follows:

- Documentation reviews
- Information gathering techniques such as brainstorming and interviewing
- Checklist analysis
- Assumptions analysis
- Diagramming techniques
- SWOT analysis
- Expert judgement

Risks are identified by using one of the mentioned methods, and gathered information is kept in risk registers. Risk registers include potential responses to risks and list, probability, impact, and causes of risks (Hulett, n.d.).

2.1.3 Qualitative Risk Analysis

Qualitative risk analysis is not an accurately quantified measure of risk, but it is commonly used to determine whether risks deserve further investigation. The following tools are used to perform this analysis.

2.1.3.1 Probability and Impact Matrix

It is stated in PMBOK Guide (2008) that each risk's importance is assessed by using a probability and impact matrix as in Figure 1. The values in Figure 1 are representative, and companies can use different scales to evaluate probabilities and impacts of risks. This tool helps project team to have an idea about effects and priorities of project risks.

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Figure 1: Probability and Impact Matrix (PMBOK Guide, 2008)

2.1.3.2 Risk Data Quality Assessment

This tool resolves quality and accuracy of the data, extent of the understanding of the risk, and information accessible about the risk (Mulcahy, 2013). This analysis helps organizations to determine whether further research is required to evaluate the risk before performing a qualitative assessment.

2.1.3.3 Risk Categorization

Heldman (2009) indicates that this technique is utilized to determine the impacts of risk on the project. Project teams organize risks in a risk breakdown structure by performing this assessment.

2.1.3.4 Risk Urgency Assessment

Organizations note risks that should move more rapidly through the process than others by using this tool (Mulcahy, 2013). Companies promptly determine responses for those risks that could occur soon.

2.1.4 Quantitative Risk Analysis

Probability and impact of risks are analyzed numerically in quantitative risk analysis. Although a qualitative analysis is easier to make, a quantitative analysis is more objective and accurate. Companies determine initial amounts of contingency reserves needed and quantified probability of achieving project targets by performing this analysis. Thaheem, Marco, and Barlish (2012) itemized quantitative risk analysis techniques: Bayesian method, belief functions method, decision making matrix, decision tree analysis, expected monetary value, failure mode and effect analysis, fault tree analysis, interviewing, Monte Carlo method, program evaluation and review technique, probability distributions, scenario analysis, sensitivity analysis, fuzzy logic, analytic hierarchy process, and break even analysis. In this study, not all of the indicated methods will be explained, but following four techniques will be clarified.

2.1.4.1 Sensitivity Analysis

Sensitivity analysis is done for the identified risks to determine which ones have a possibly high effect on the project objectives (Norris, Perry, & Simon, 2000). In other words, critical items in the risk register are specified by performing sensitivity analysis. Heldman (2009) displayed sensitivity analysis data in tornado diagrams such as shown in Figure 2. Tornado diagrams provide a ranking of the project risks based on their relative contributions to the project uncertainty.

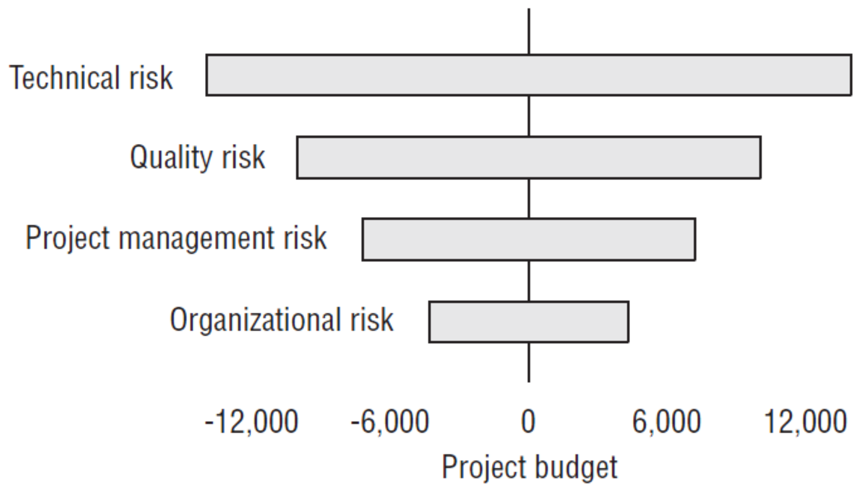

Figure 2: Tornado Diagram (Heldman, 2009)

2.1.4.2 Expected Monetary Value Analysis

Expected monetary value (EMV) is a tool for risk quantification that is calculated by multiplying the probability of the risk by its impact. Mulcahy (2013) argues that EMV is a positive amount for opportunities, but it is presented as a negative number for threats.

$$\mathrm{EMV} = \mathrm{P} \times \mathrm{I} \tag{1}$$

Where;

EMV : Expected monetary value

P : Probability

I : Impact

2.1.4.3 Monte Carlo Analysis

Many scenarios for the project cost and schedule are analyzed, and impacts of the identified risks are generally calculated by computer in Monte Carlo analysis. PMI (2008) also argues that, in a simulation, the project model is iterated several times with the data such as cost estimates and activity durations elected randomly for each computation from the probability distributions of these values. Heldman (2009) indicates, "Modelling allows you to translate the potential risks at specific points in the project into their impacts" (p. 261-262). Monte Carlo analysis will be studied in detail under the title of contingency estimation techniques.

2.1.4.4 Decision Tree Analysis

Decision tree method is a graphical tool used to evaluate different conditions and the inferences of each case, and this analysis is performed to compare the cases for selecting the optimum option (Thaheem et al., 2012). Decision trees are diagrams that display correlative decisions, their impacts, and probabilities.

Expected monetary values are used in decision tree analysis to decide on the correct alternative.

2.1.5 Planning Risk Responses

After risk identification and quantification processes are completed, risk responses are determined. Risk responses are planned to remove the identified threats to the project and increase the probability of the analyzed opportunities. Moreover, contingency plans and fallback plans for the risks that can not be removed by the risk response plan are also prepared in this stage of risk management.

There are different strategies used in the risk response plan, and these strategies are chosen according to the type of risk. PMI (2008) describes strategies chosen to deal with threats as follows:

- **Avoid:** Adjusting the project management plan is implemented to eliminate the threat completely in this strategy. Examples of this approach are extending the schedule, reducing the scope, or closing the project entirely.
- **Transfer:** Another party is made responsible for the risk in this strategy. For instance, purchasing insurance, performance bonds, warranties, and outsourcing the work are used to transfer the risk.
- **Mitigate:** This action is reducing the probability or the impact of a negative risk. Performing more tests or selecting a more reliable supplier are cases of mitigation approach.

- **Accept:** This action implies that the project management plan is not changed to deal with a risk. Active acceptance approach is to determine a contingency reserve consists of time and money to cover the risks.

Further, Mulcahy (2013) defines strategies for opportunities as follows:

- **Exploit:** Ensuring occurence of the opportunity.
- **Enhance:** Raising the probability of the risk.
- **Share:** Going into a partnership to achieve the opportunity.
- **Accept:** Accepting existence of a positive risk, but not pursuing it.

According to the decisions taken by companies in the planning risk responses process, project management plan, including cost, schedule, and quality management plans, may be revised. Moreover, results of this process are added to the risk register.

The most important action in this process is to finalize contingency or reserve amounts obtained by quantitative analysis, and final contingency determination methods will be explained under the title of contingency estimation techniques. Reserves are assessed for both time and cost; however, only cost reserves are examined in this study. Reserves, added to project cost estimates, are divided into two groups: contingency reserves used for identified risks and management reserves used for unidentified risks (Mulcahy, 2013). In this study, contingency reserves and management reserves will be considered together, and total of these reserves will be named as contingency amount used to cover costs resulting from both identified and unidentified risks.

2.1.6 Controlling Risks

In this stage of risk management, new risks are identified and analyzed throughout the project duration. Effectiveness of the risk management plan is evaluated, and risk response plans are updated in this process. Further, remaining risks are controlled by developing response strategies.

2.2 Contingency

Construction companies do not usually have a chance to analyze the international construction project conditions accurately due to short time for preparing the offer and limited information in the tender documents. Companies encounter with unique risks in international markets, and some unpredictable and unknown factors may be faced by construction companies. Zeitoun and Oberlander (1993) claim that construction projects are infamous for running over budget due to limitations in the bidding stage and high risk.

Contingency amount is used to cover expenses because of financial risks and uncertainties. Therefore, contingency determination is very crucial for success in achieving the project targets, competitiveness during the bidding stage, and the company’s profitability. Baccarini (2004) emphasizes that the assessment of cost contingency and its sufficiency have a severe importance for projects.

Contingency is a complicated concept, and there is not a single definition for it covering all fields. Kimmons (1990) describes contingency as “project management’s least understood term” (p. 95), and he adds that there is insufficient mutual understanding of what it is. Therefore, different approaches to the concept of contingency will be defined in this research to make the notion clear.

The understanding of contingency varies from person to person, and Jackson (2003) observed some perspectives of different members in a project on contingency as follows:

- To management, contingency is an amount of money that will not be spent and returned as profit at the end of the project.
- To engineers, contingency is a saving budget that can be used to defray the costs out of underestimation or omission.
- To the construction team, it is a supply utilized to cover further costs arising from extension of time, construction obstacles, and inefficiency.
- To the cost engineers, contingency is a capital that can be used to defray the increased costs owing to undervaluation of project costs and inadequacy of definition at the assessment phase.

Experience has proved that contingency is an amount of money that must be added to the main estimation to cover costs resulting from project definition or technological uncertainties (Burroughs & Juntima, 2004). County of Albemarle Office of Facilities Development (OFD, 2012) refers to contingency as a risk allocation to be used for identified or unidentified risks. Lee and Chang (2004) state that contingency, which is also called as “risk mark-up,” is a fund allocated for potential uncertainties related to a construction project in the offers.

As mentioned under the title of planning risk responses, contingency can be examined in two groups: contingency reserve and management reserve. Two levels of contingency are illustrated in Figure 3 (Broadleaf, 2014), and the concept of contingency includes both of these levels in this study.

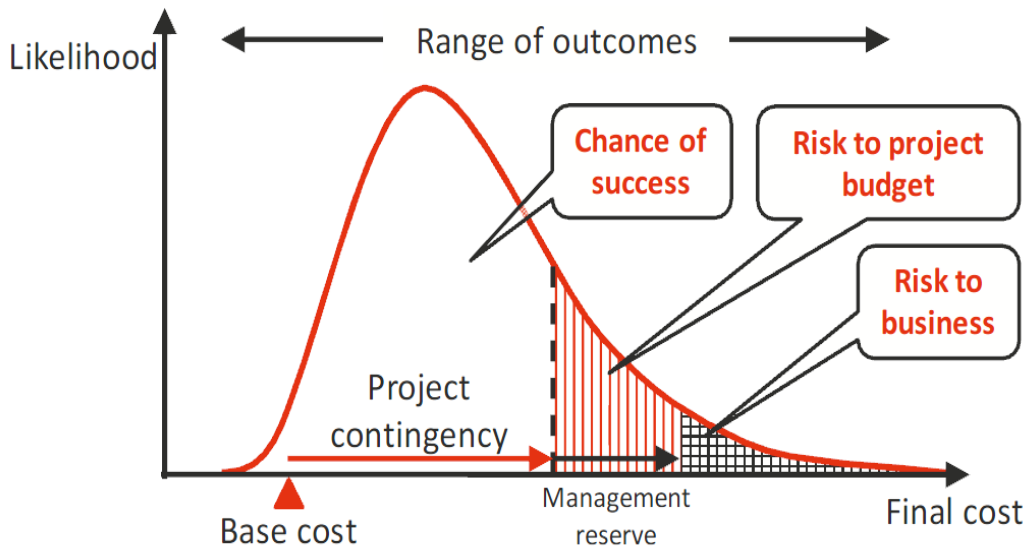

Figure 3: Contingency and Management Reserves (Broadleaf, 2014)

Eliminating the possibility of cost overrun for a project is the purpose of contingency allowance (Boukendour, 2005). County of Albemarle Office of Facilities Development (OFD, 2012) emphasizes that contingency determination aims to consider economic constraints that could be troublesome for the project schedule or budget.

In conclusion, comprehending the concept of contingency is necessary to make not only accurate but also competitive cost estimates. Some financial risks are identified during the risk management processes; however, companies can also encounter with unknown risks. Therefore, a contingency amount, comprises two levels of contingency, should be determined to achieve the project targets. There are some techniques for determining the contingency amount.

2.2.1 Contingency Estimation Techniques

Various methods are available to calculate and determine contingency amount. Deterministic techniques are typically used to derive a margin of amount; however, probabilistic and parametric methods are also developed by means of understanding the importance of contingency estimation. These techniques can be listed as noted below:

1. Predetermined Percentage
2. Expert's Judgement
3. Program Evaluation and Review Technique (PERT)
4. Estimating Using Risk Analysis (ERA)
5. Monte Carlo Analysis
6. Artificial Neural Network (ANN) Model
7. Regression Analysis

2.2.1.1 Predetermined Percentage

A predetermined percentage of the base estimation is used as the contingency rate in this method. Addo (2015) defines this approach as a subjective way commonly derived from instinct, past experience, and historical information, and he claims a percentage between 5% and 10% is added to the most probable evaluation of the known works. This traditional method is easy to use, and its results are consistent for small and ordinary projects; however, the method fails to estimate proper rates for unique and poorly defined projects.

2.2.1.2 Expert's Judgement

In this method, skilled estimators and experienced project management team determine a contingency ratio based on their experiences and intuitions. The expert judgement technique differs from the predetermined percentage approach in considering specific risk factors and base estimation competitiveness (Burroughs & Juntima, 2004).

Experts can use either a single percentage for all cost items or different percentages for different cost items. Estimating different contingency rates for every work separately is more detailed and efficient than using a percentage for all works, but it is a time consuming approach.

Main disadvantage of this method is subjectivity such in the predetermined percentage technique, because the ability, experience, and motivations of the experts may differ considerably (Burroughs & Juntima, 2004).

2.2.1.3 Program Evaluation and Review Technique (PERT)

PERT was developed in the late 1950's for the U.S. Navy's Polaris Project, and it enables to decrease both the project duration and cost ("PERT," n.d.). PERT is a probabilistic technique assumes a beta probability distribution for the estimates. In addition, it is considered as a variation of the central limit theorem. This method provides appropriate contingency amounts in comparison with traditional deterministic methods.

Instead of calculating a value, three values are calculated and then their average is taken to eliminate uncertainties and biases. Three estimates are called as optimistic cost (c_o), pessimistic cost (c_p), and most likely cost (c_m). Ergin (2005) states that quantitative approach based on historical information or qualitative way based on experience can be used to determine these costs depending on the availability of the project data. He also indicates that three estimates are determined by the estimator's experience when there is not adequate data supporting the estimate. At that time, the expected cost (C_e) and the variance (V_v) are calculated as follows:

$$C_e = \frac{\lfloor c_o + c_p + (4 \times c_m) \rfloor}{6} \tag{2}$$

$$V_v = \left\lfloor \frac{(c_p - c_o)}{6} \right\rfloor^2 \tag{3}$$

He adds that the expected cost is the arithmetic mean of the sample data set from c_1 to c_n when there is a set of historical data supporting the estimate.

$$C_e = \frac{c_1 + c_2 + \cdots + c_n}{n} \tag{4}$$

Where;

n : Total number of values in the sample data set

Kamalesh, Ahmed, and Ogunlana (2009) remark that contingency amount is estimated as the difference between the expected cost which is calculated based on the probability distribution assigned to the data and the wanted "comfort level" by the management team (as cited in Hobbs, 2010).

If estimates are determined based on someone’s experience, they may be subjective. Moreover, PERT assumes a beta distribution for these cost estimates, but actual distribution may be different. Even if estimates are obtained from historical data, independent variables are necessary for the estimation; therefore, an extensive and accurate database is required to perform this method.

2.2.1.4 Estimating Using Risk Analysis (ERA)

In this method, probabilities and impact amounts of identified risks are used to determine a contingency amount. Further, the expected monetary value theory that was clarified under the title of quantitative risk analysis is utilized to perform ERA.

2.2.1.5 Monte Carlo Analysis

Burroughs and Juntima (2004) explain that a probability distribution is selected for each data of cost items in Monte Carlo analysis, and the simulation tool arbitrarily assigns a possible result from each item's distribution. The results for the individual cost items are added or mathematically combined to obtain a project cost. The range of the iterative results can be used to determine optimistic, pessimistic, and most likely cost values. Expected project cost is calculated based on the selected probability distribution for the project cost results, or it can be estimated as the average of iteration results. Finally, contingency amount is determined as the difference between the expected cost and the cost corresponds to the confidence level specified by the management team.

The main advantage of this technique is that it allows confidence levels, and it can be used for any assessment or cost analysis (Burroughs & Juntima, 2004). Moreover, this analysis is generally performed by softwares allow to select different probability distributions for various data contrary to PERT. Another benefit of this approach is that jointly distributed random items in which correlations may be observed can also be simulated (Cullen & Frey, 1998, p.202).

Burroughs and Juntima (2004) considers that the most important deficiency of this approach is that the evaluation components for which possible result distributions are being designated are not risk drivers; therefore, the assigned distributions may be inconsequential. Further, Monte Carlo analysis is more time consuming and complex in comparison with the expert's judgement approach or PERT. In addition, selection of a suitable probability distribution for cost items and performing correlations among the items are the main difficulties of simulation methods (Sonmez, 2008).

2.2.1.6 Artificial Neural Network (ANN) Model

ANN model is a parametric tool that is used to estimate a variable dependent on some parameters by utilizing previous data. An artificial neural network that is illustrated in Figure 4 comprises input, output, and hidden nodes. These nodes are linked by neurons that are a processing component takes one or more inputs and forms an output by using an activation function. An ANN is established by specifying connections between nodes and assigning weight values to these connections.

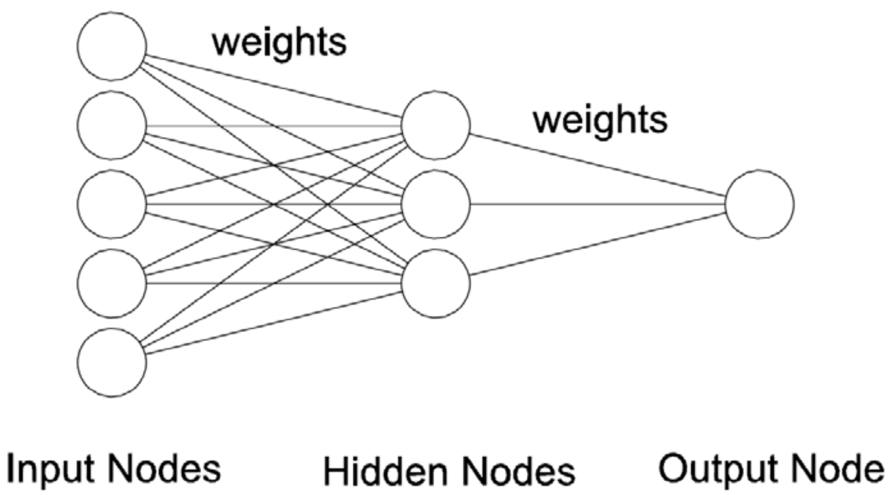

Figure 4: Structure of an ANN

ANN models are generally simulated by using software applications. In the hidden layer, neurons generate outputs by calculating the sum of weighted input values, and the activation function of the artificial neurons is formulized as follows:

$$A_j(x, w) = \sum_{i=1}^{n} x_i \times w_{ji} \tag{5}$$

Where;

A(x, w) : Activation function of the artificial neurons

x : Input value

w : Weight

i and j : Indices of summation

n : Total number of inputs

Gershenson (2003) remarks that if output function is identical with the activation function in the hidden layer, then the neuron is named as linear. To eliminate the limitations of linearity, functions such as unit step (threshold), sigmoid, piecewise linear, and Gaussian are used as activation functions.

A suitable output can be obtained by decreasing the error that is the difference between the actual and the requested result, and weights should be adjusted to reduce the error (Gershenson, 2003). The error of the network is calculated as follows:

$$E(x, w, d) = \sum_j \left(O_j\,(x, w) - d_j\right)^2 \tag{6}$$

Where;

E(x, w, d)	: Error function of the ANN
x	: Input value
w	: Weight
d	: Actual value
j	: Index of summation
O(x, w)	: Output function

Chen (1999) developed an artificial neural network to predict cost and time variances at the early stages of projects. He evaluated risk effects on project cost and time estimates to determine a contingency amount. Polat (2012) established an ANN model that helps construction companies to determine contingency amount for international construction projects.

ANN model, which is a parametric estimating technique, makes a point estimate for the analyzed item, and this point estimate is not adequate to analyze the level of uncertainty (Sonmez, 2008). In addition, many proper practices are necessary to obtain an output that is close enough to the desired result by using a neural network (Timmy, n.d.). However, ANN method provides more efficient results in comparison with the deterministic methods, and it includes the information of parameters as an advantage over the probabilistic techniques.

2.2.1.7 Regression Analysis

Regression analysis is a statistical method used to analyze relationships between parameters, and it is an alternative parametric approach to the ANN model. Lind, Marchal, and Wathen (2005) indicate that the purpose of regression is to find the equation of a single line that fits the existing data of parameters (as cited in Eratak, 2014).

Regression analysis depends on certain data, not an estimated probability distribution such in probabilistic techniques (Burroughs & Juntima, 2004). Although extensive information about the projects and much time are required to establish the model in the first stage, implementation of the regression method is very easy later (Ergin, 2005).

Cook (2006) used multiple linear regression analysis to determine contingency amounts in construction projects. He analyzed data of 243 construction projects in order to identify valid indicators of risk factors and establish a predictive model for construction cost overruns. Lowe, Emsley, and Harding (2006) developed linear regression models to predict the construction cost of buildings by using 286 sets of data collected in the United Kingdom. Sonmez, Ergin, and Birgonul (2007) presented a methodology based on regression and correlation analyzes to determine the impacts of possible factors on contingency rate.

The main limitation of this approach is that a straight line fits the general trend of the data is used; therefore, the estimated linear function may not provide a fine fit to the project data. Further, this method does not provide a range estimate, and the level of uncertainty can not be analyzed efficiently.

Setting a regression model and details of this technique will be explained under the title of efficient frontier, regression, and bootstrap analysis.

2.2.2 Review of Contingency Estimation Techniques

Contingency estimation is one of the major challenges faced by project management teams. After the importance of contingency had been understood by companies, use of risk analyzes in projects increased between the years of 1998 and 2003 as shown in Figure 5 (Burroughs & Juntima, 2004). This tendency has been going on for construction projects, and use of the predetermined percentage technique has been decreasing.

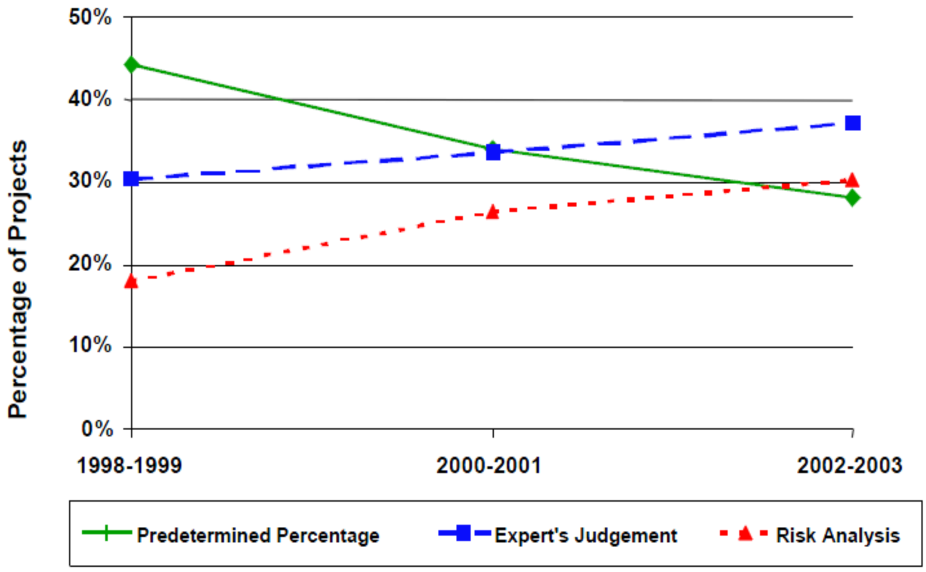

Figure 5: Use of Contingency Estimation Techniques (Burroughs & Juntima, 2004)

Each mentioned estimation technique has advantages and disadvantages. To evaluate four commonly used estimation techniques, Burroughs and Juntima (2004) examined Contingency Performance Indicator (CPI) that is defined as the absolute value of actual contingency rate minus estimated contingency rate (Figure 6). They came up with that risk analysis such as Monte Carlo analysis and regression model provide more precise estimates in comparison with the predetermined percentage and expert's judgement methods for well defined projects. When poorly defined projects were observed, the worst estimates were obtained from risk analysis that stands for probabilistic methods like Monte Carlo analysis.

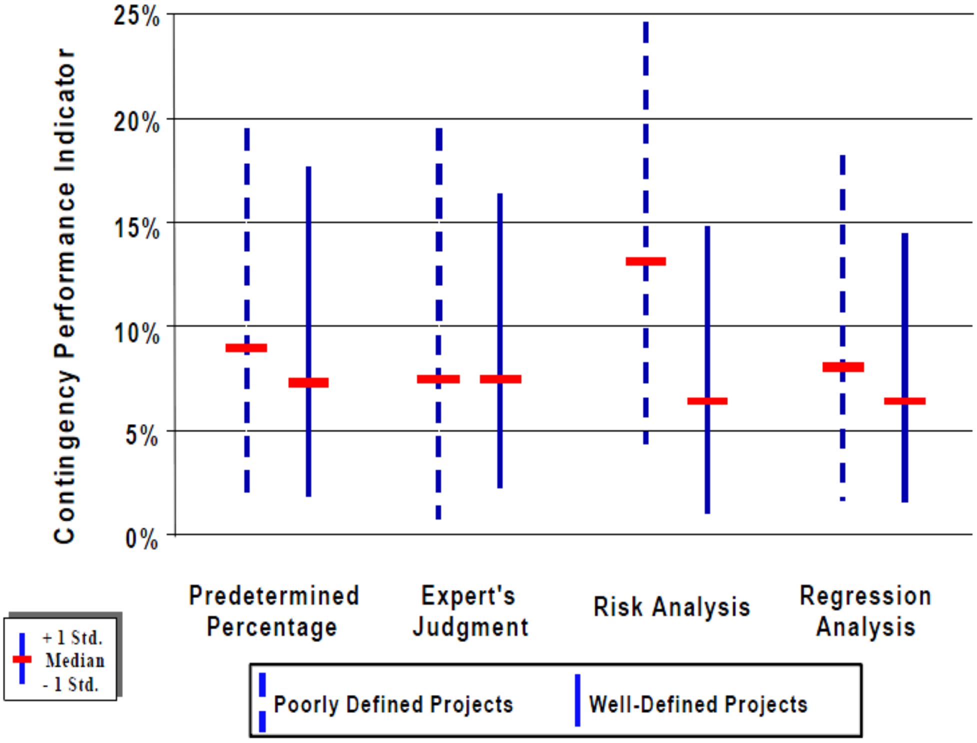

Figure 6: Examination of CPI for Contingency Estimation Techniques (Burroughs & Juntima, 2004)

The popular wisdom of that probabilistic method provides more accurate contingency prediction than the traditional approach may not be valid in all circumstances. Weaknesses of the techniques, project risk conditions, and the level of project definition can affect the efficiency of the results. Therefore, contingency estimation technique should be selected carefully by considering the project conditions in order to get the optimal contingency rate.

Burroughs and Juntima (2004) concluded that regression analysis provides consistent and proper approximations. Moreover, integrating regression analysis with bootstrap method, which is a sampling technique, gathers the advantages of probabilistic and parametric estimation approaches together. The decision support tool developed in this study runs an integrated method that comprises regression analysis and bootstrap method.

2.3 Markup and Profit

Understanding the concept of markup and its components will be helpful to comprehend portfolio contingency-profit analysis. Therefore, markup and profit notions will be explained under this title.

2.3.1 Bid Price

Construction bids include many cost items, and each of these cost items is calculated or estimated by using different approaches. Lee (2007) classifies costs as follows:

- Direct costs: subcontractor prices, labor, material, and equipment costs
- Indirect costs: project overhead
- Markup: contingency, profit, and general overhead

Direct and indirect costs are calculated by cost estimators according to the project documents, historical data, and collected offers. A quantity take-off is prepared to determine direct and indirect costs, and total of these costs is called as total construction cost.

Bid price, which will be called as the contract price after the contract is signed by the parties, is the total of construction cost and markup amount. Bid prices could be estimated by using different bidding strategies such as game theory based, statistics based, and cash flow based strategies. Jha (2011) states that all statistical bidding strategies aim to assist decision makers in selecting an optimal markup level. There are mainly two proposed statistical bidding models: Friedman's model (1956) and Gates' model (1967).

Friedman (1956) developed an expected value model describing the bidding situation with probabilistic equations. He found the following equations:

$$P_{kc} = \prod_{i=1}^{n} P_{bc\,i} \quad (7)$$

$$P_{uc} = (P_{btc})^n \quad (8)$$

In addition, Gates (1967) proposed another bidding strategy model, and he used the following formulations:

$$P_{kc} = \frac{1}{\left[\sum_{i=1}^{n} \frac{(1 - P_{bc\,i})}{P_{bc\,i}}\right] + 1} \quad (9)$$

$$P_{uc} = \frac{1}{n \times \left[\frac{(1 - P_{btc})}{P_{btc}}\right] + 1} \quad (10)$$

Where;

i : Indices of summation

n : Total number of competitors

P_{kc} : Probability of winning against a number of known competitors for a given markup

$P_{bc\,i}$: Probability of beating competitor i

P_{uc} : Probability of winning against a number of unknown competitors for a given markup

P_{btc} : Probability of beating one typical competitor

2.3.2 Markup

The amounts added to the estimated construction cost could be defined as markup amount. Jha (2011) indicates that markup quantity is the sum of profit amount, overhead cost, and contingency amount that includes both contingency reserve and allowances for risk.

Jha (2011) explains determination of optimum markup as follows:

1. An initial markup percentage of total construction cost is assumed, and it is increased in small increments of one percentage up to the optimal rate.
2. Probabilities of winning against different competitors could be calculated by using previous bidding information and historical data.
3. The probability to win at markup level M is calculated by using Friedman's model.
4. Expected markup amount is determined by using the following equation:

$$\text{Expected markup amount} = \mathrm{MA_M} \times \mathrm{P_M} \tag{11}$$

Where;

$\mathrm{MA_M}$: Markup amount for a given markup percentage M

$\mathrm{P_M}$: Probability of winning at the markup percentage M

5. Markup percentage is increased to M+1, and the expected value of markup amount is calculated again as described in steps 2 to 4.

6. Based on the above values of markup percentage and expected markup amount, a curve is plotted for markup percentage versus expected markup amount.
7. The optimum markup percentage is read from the obtained plot. Let this be M1.
8. Steps 1 to 7 are repeated for Gates' model also, and optimum markup is read from the obtained plot. Let this be M2.
9. The average markup (M1 +M2)/2 can be taken as the optimum markup.

2.3.3 Overhead Costs

In addition to the construction costs including material, equipment, and labor costs, bid prices contain overhead costs. Unified Facilities Criteria (UFC, 2010) indicates that overhead costs can not be assigned to a specific construction activity. Overhead costs are generally divided into two groups:

- Project overhead: mobilization costs, project management team's salaries, security cost, etc.

- General overhead: office rental fee, legal expenses, electricity fee, advertising, etc.

UFC (2010) expresses that overhead costs in construction projects are commonly calculated based on historical data and experience of companies; however, these costs may vary from project to project, and a detailed estimation is required for complex projects.

2.3.4 Profit

Zions Bank (n.d.) indicates that there are several ways to measure a company's profits, and three common techniques that are used to analyze profitability are listed as follows:

- Margin (or profitability) ratios
- Break-even analysis (based on revenues and on units sold)
- Return on investment and assets

In this study, profitability will be measured by using net profit that is a margin ratio. Zions Bank (n.d.) explains the most important margin ratios as follows:

- Gross Profit = Net Sales – The Cost of Goods Sold
- Operating Profit = Gross margin – Selling and Administrative Expenses
- Net Profit = Operating Profit (plus any other income) – Additional Expenses - Taxes

Net profits of construction projects are calculated as the difference between total income and total expenses incurred throughout the project duration. Profit rates in construction project bids are generally determined based on historical data and experience of companies. Unified Facilities Criteria (UFC, 2010) states that weighted guidelines method can also be used to determine profit rate by taking into consideration the following factors: degree of risk, relative difficulty of work, size of the job, period of performance, contractor's investment, assistance by government, and subcontracting.

2.4 Risk-Return & Contingency-Profit Relationships

Risk and return relationship has been examined by many researchers, and different relationships such as positive, negative, curvilinear, and polynomial have been presented. Ross (1973) proposes a linear positive relation between risk and return according the economic theory of agency. Next, Kahneman and Tversky (1979) developed the prospect theory that introduces a curvilinear relationship between risk and return. They assume an average reference point, and performing above or below this reference point influences managers' assessment of risks. They assert that executives act as risk seekers who prefer riskier alternatives when performing below the reference point; however, executives display risk averse behaviors by preferring less risky alternatives when performing above the reference point. In addition, some researches have claimed that there could be multiple reference points instead of a single reference point. Executives are generally increase risk taking when performing either quite below or quite above their performance reference points (March, 1994). Later, Bowman (1980) observed remarkable negative relationship between risk and return during his examination of various firms from more than 50 industries. He found that a remarkable amount of companies, took high risks, made low profits, and these results created a risk-return paradox (Bloom & Milkovich, 1993).

Besides the mentioned three approaches to relationship between risk and return, Mukherji, Desai, and Wright (2008) examined a polynomial relationship. They suggest that, "In addition to an average or industry reference point, there exists a failure reference point below the average and a success reference point above the average" (p. 249). They claim that their approach could clarify most of the anomalies faced in empirical investigations, and different ways are integrated in their study. They illustrate a polynomial risk-return relationship model as shown in Figure 7.

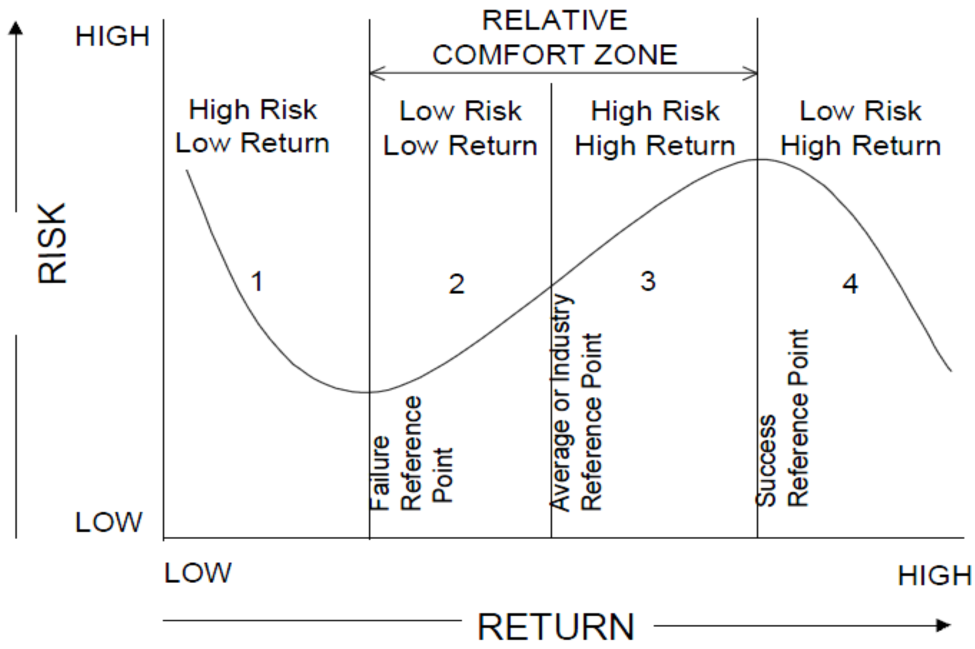

Figure 7: A Polynomial Risk-Return Relationship Model (Mukherji et al., 2008)

Mukherji et al. (2008) claim that executives of companies performing below their failure reference point will display risk seeking behaviors to move to region 2 shown in Figure 7. They also indicate that managers of firms operating above their success reference point think they have adequate resources and high organizational abilities, and their risky decisions do not affect their companies. In their model, there is a positive relationship between risk and return in the relative comfort zone shown in Figure 7, and people display risk averse behaviors in this region.

It should be pointed out that most researchers, including the investigators mentioned above, assume risk to be measurable by the variation about the mean of the profit measure. The variance of an investment is the expected value of the sum of the squared deviations from the mean, and the standard deviation is the square root of the variance.

As it was previously stated, risk is an uncertain situation that, if it occurs, may have negative or positive impacts on investment goals. Contingency amounts are used to cover expenses resulting from these impacts for project-based transactions. Contingency amounts are quantifiable items of risk. Moreover, calculating return on investments is a profitability measurement technique. Considering close relations between risk & contingency and return & profit, it is expected that the contingency-profit relationship in construction industry is very similar to the risk-return relationship mentioned in the investment decisions. In this study, contingency amounts will be used as a measure of risk instead of variance or standard deviation, and project profits will be used as a measure of profitability instead of return on investments. A contingency-profit trend line will be fit to the historical data in order to determine a risk-return curve for the international project to evaluate contingency-profit relationship for construction portfolios.

CHAPTER 3

EFFICIENT FRONTIER, REGRESSION, AND BOOTSTRAP ANALYSIS

3.1 Efficient Frontier

The efficient frontier is a tool in Modern Portfolio Theory developed by Harry Markowitz in 1952. The efficient frontier aims to find the optimal portfolio of investments, and this tool is valid not only in portfolios of financial assets but also in portfolios of projects. Roychoudhury (2007) defines the efficient frontier as a borderline consisting of optimal portfolios in the risk-profit plane. Chen, Chung, Ho, and Hsu (2010) indicate, “The Markowitz Efficient Frontier is the set of all portfolios of which expected returns reach the maximum given a certain level of risk” (p. 165).

Markowitz (1952) measured return by calculating the expected value of the probability distribution of expected returns for a portfolio. Chen et al. (2010) state that risk is assumed to be quantitative by the variability around the expected value of the probability distribution of returns. In MPT, risk is measured by calculating the variance and standard deviation.

Expected return for n assets, variance, and standard deviation can be calculated as follows:

$$E(r_p) = \sum_{i=1}^{n} w_i \times E(r_i) \tag{12}$$

$$Var(r_p) = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \times w_j \times \rho_{ij} \times \sigma_i \times \sigma_j \tag{13}$$

$$\sigma_p = \sqrt{Var(r_p)} \tag{14}$$

Where;

r_p : The return on portfolio p

E( ) : The expected value of the variable in the parentheses

n : Total number of securities

i and j : Indices of summation

w_i and w_j : The proportion of the funds invested in securities i and j

$\sum_{i=1}^{n} w_i$ = 1.0

$\sum_{j=1}^{n} w_j$ = 1.0

r_i and r_j : The returns on i^{th} and j^{th} securities

Var( ) : The variance of the variable in the parentheses

ρ_{ij} : Correlation coefficient between the rates of return on security i (r_i) and security j (r_j)

σ_p, σ_i, and σ_j : Standard deviations of r_p, r_i, and r_j respectively

As it was previously explained under the title of risk-return & contingency-profit relationships, there is a polynomial relationship between risk and return. In parallel with previously discussed approaches, expected return and standard deviation, which are used as measures of profit and risk respectively in MPT, have a polynomial relationship as illustrated in Figure 8 (Chen et al., 2010).

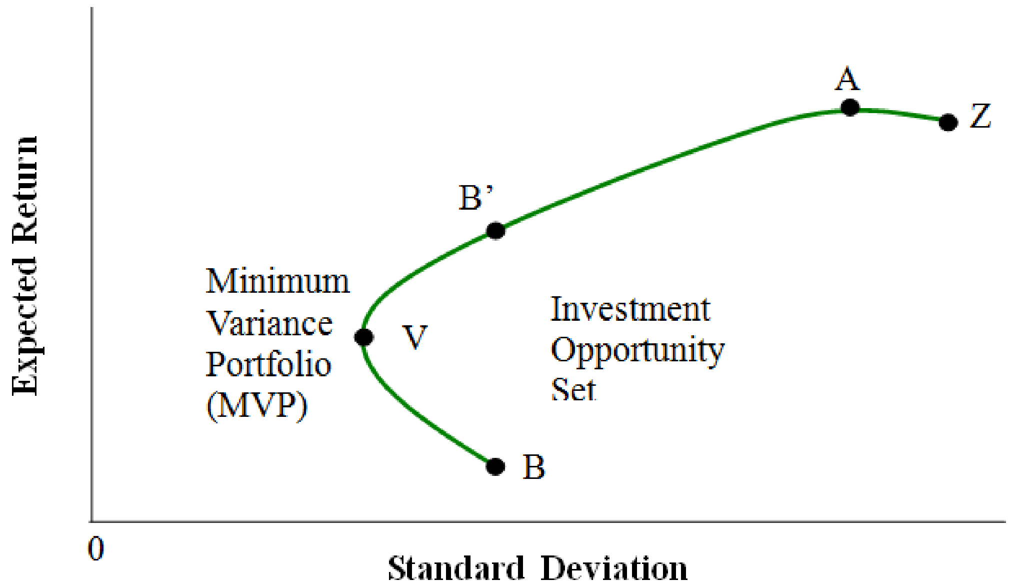

Figure 8: Standard Deviation-Expected Return Relationship (Chen et al., 2010)

Chen et al. (2010) explain that the region within the curve BVAZ in Figure 8 represents all possible portfolios. Portfolios that lie above the point A or below the point V can be rejected owing to inefficiency. They indicate that the curve VA is the efficient frontier, which shows portfolios that provide the highest expected return for each level of portfolio standard deviation. Discovery Invest (2012) demonstrated the concept of the efficient frontier as shown in Figure 9.

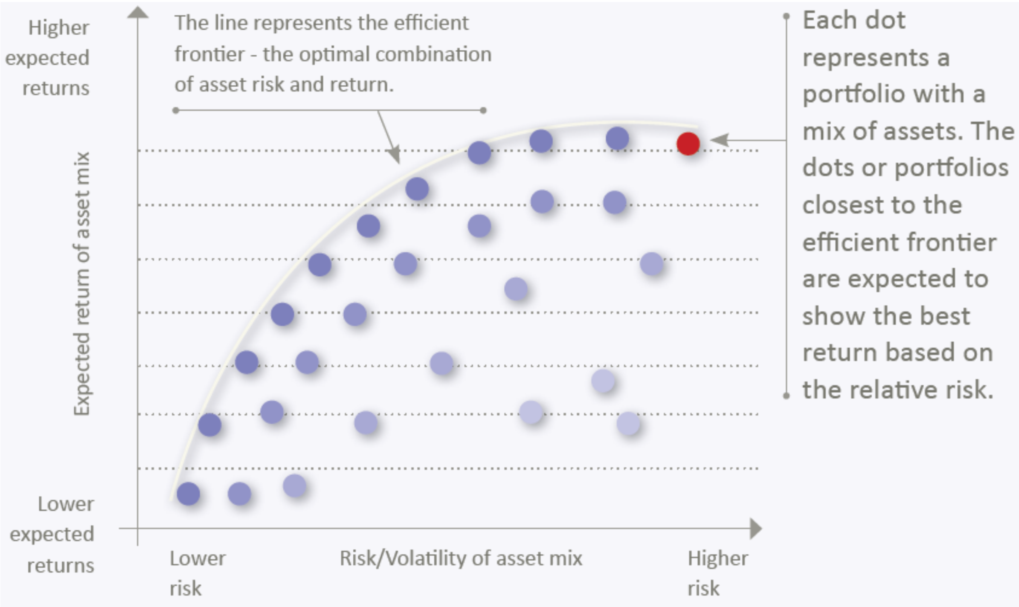

Figure 9: The Efficient Frontier (Discovery Invest, 2012)

3.2 Regression Analysis

The purpose of regression analysis is to fit a curve for the existing data while decreasing the sum of squared error, and regression models are utilized to indicate a dependent variable in terms of independent variables (Karanci, 2010). As stated previously, regression analysis is a statistical method used to analyze relationships between parameters. Regression models are classified into two categories: simple regression, which includes a single explanatory variable, and multiple regression that contains numerous independent variables.

In the simple regression analysis, there are a dependent variable (y), an independent variable (x), and regression coefficients (β_0 and β_1). The simple regression model can be formulized as follows:

$$y = \beta_0 + \beta_1 \times x + u \tag{15}$$

Where;

β_0 : The y-intercept

β_1 : The slope of the relationship

u : The error quantity that takes into account all factors that are not included in the model

Cottrell (2011) state that some assumptions are required on the subject of error to work with regression models. He used i as a summation index for the observations on the data pairs (x, y), and he assumed three situations for the error term as indicated below:

- $E(u_i) = 0$, u has a mean of zero for all i
- $E(u_i^2) = \sigma_u^2$, u has the same variance for all i
- $E(u_i, u_j) = 0, \ i \neq j$, no correlations across observations

In the multiple regression analysis, there are a dependent variable (y), various independent variables (x_1, x_2, ..., x_n), regression coefficients (β_0, β_1, β_2, ..., β_n), and the error term (u). The multiple regression model can be formulized as follows:

$$y = \beta_0 + \beta_1 \times x_1 + \beta_2 \times x_2 + \dots + \beta_n \times x_n + u \tag{16}$$

The most common technique for estimating regression coefficients is the least squares method. A large number of data will form large matrices, then least squares technique can be applied by using data analysis tools or computer programs such as Excel and Matlab. In the case of that regression analysis will be performed with m data groups ($x_{1,i}$, $x_{2,i}$, ..., $x_{n,i}$, y_i), the regression coefficients are calculated by the least squares method as follows:

$$\underline{x} = (A^T A)^{-1}(A^T \underline{b}) \tag{17}$$

Where;

$\underline{x} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_n \end{bmatrix}_{(n+1)\times 1}$: The coefficients matrix

$A = \begin{bmatrix} 1 & x_{1,1} & x_{2,1} & \cdots & x_{n,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots & x_{n,2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{1,m} & x_{2,m} & \cdots & x_{n,m} \end{bmatrix}_{m\times(n+1)}$: The independent variables matrix

A^T : The transpose of matrix A

$(\ )^{-1}$: The inverse of the matrix in the parentheses

$\underline{b} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix}_{m \times 1}$: The dependent variables matrix

As it is also understood from Formula 17, the purpose of the least squares method is to obtain an approximating function that fits the general trend of the data. In order to assume the mean of errors to be zero, goodness of fit for the derived function should be checked. There are mainly four different indicators of the goodness of fit, which are explained below.

1. Maximum Error ($\underline{E}$):

$$\underline{E} = \max_{1 \le i \le n}\{|y_i - \hat{y}_i|\} \tag{18}$$

2. Mean Absolute Percentage Error (MAPE):

$$\text{MAPE} = \left(\frac{1}{n} \times \sum_{i=1}^{n} \frac{|y_i - \hat{y}_i|}{|y_i|}\right) \times 100 \tag{19}$$

3. Sum of Squared Residuals (SSR):

$$\text{SSR} = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \tag{20}$$

4. The Coefficient of Determination (R^2):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \tag{21}$$

Where;

i : Index of summation

n : Total number of data

y_i : Actual value of the dependent variable for the i^{th} data

$\hat{y}_i$: Predicted value of the dependent variable for the i^{th} data

$\overline{y}$: Mean value of the dependent variable

In conclusion, the derived regression model should be checked by using one of the mentioned indicators in order to have an idea about the goodness of fit. If the quality of fit is adequate, it is acceptable that the error has a mean of zero, and there is no necessary for higher degree models.

3.3 Bootstrap Method

Efron (1979) developed bootstrap method that is a resampling technique used for different purposes. Bootstrap method, which is a computer-aided technique, has been used in various statistical operations such as approximating standard error of a sample estimate, estimating a confidence interval, regression analysis, and performing hypothesis tests.

Simon and Bruce (1991) indicate that bootstrap method, which is simple to learn and perform, does not have excessive mathematical equations and limiting assumptions. Bootstrap methods are more tractable than conventional methods that may be analytically difficult or useless due to the unfulfilled assumptions (Johnson, 2001).

Bootstrap method aims to reproduce investigation information by resampling data from the examined sample, and it randomly selects r new samples with the same size as the observed data by replacing from the realized data (Sonmez, 2008). Bootstrap method does not sample from the population, but it samples with replacement n times from the observed data (Johnson, 2001).

3.3.1 Bootstrap Method on Regression Models

Integrating bootstrap method with regression models helps to obtain a range for the estimation and approximate the distribution of the regresssion coefficients. In addition, the application of bootstrap method to regression models gathers the advantages of probabilistic and parametric estimation approaches together. The decision support tool developed in this study runs bootstrap method on regression models. The basis of this resampling method and its application to regression model will be explained in this subtitle.

A multiple regression model for contingency rate estimation can be expressed as follows:

$$\mathrm{cr} = \beta_0 + \beta_1 \times x_1 + \beta_2 \times x_2 + \ldots + \beta_n \times x_n + u \tag{22}$$

Where;

cr : Contingency rate

$x_1, x_2, \ldots, x_n$: Independent parameters affecting the contingency rate

$\beta_0, \beta_1, \ldots, \beta_n$: Regression coefficients

u : The error term that will be assumed to be zero.

The investigated data pairs, X = {(cr_1, $x_{1,1}$, $x_{2,1}$, ..., $x_{n,1}$), (cr_2, $x_{1,2}$, $x_{2,2}$, ..., $x_{n,2}$), ..., (cr_m, $x_{1,m}$, $x_{2,m}$, ..., $x_{n,m}$)}, obtained from m completed projects for contingency rate with n different parameters are resampled by bootstrapping. Integers (i_1, i_2, ..., i_m) from 1 to m, each of which has an election probability of 1/m, are selected randomly to perform resampling. The bootstrap data set, X* = {(cri_1, $xi_{1,1}$, $xi_{2,1}$, ..., $xi_{n,1}$), (cri_2, $xi_{1,2}$, $xi_{2,2}$, ..., $xi_{n,2}$), ..., (cri_m, $xi_{1,m}$, $xi_{2,m}$, ..., $xi_{n,m}$)}, is established by corresponding members of X. Efron (1979) used star notation to indicate that X* is a resampled version of X. Sonmez (2008) states, "The bootstrap data set consists of members of the original data set, some appearing zero times, some appearing once, some appearing twice or, more" (p. 1012).

The ordinary least squares method is used to determine the regression coefficients. The coefficients (β_0, β_1, ..., β_n) are initially determined by using the observed data set (X). Next, the bootstrap data sets (X*) are used to obtain the regression coefficients for the regression model expressed in Formula 22. Bootstrapping process can be performed by using sampling add-in on the tab of data analysis in Excel or benefiting from other computer programs. Bootstrapping procedure is repeated several times in order to obtain a probability distribution function for the predicted variable that is contingency rate in this study.

The error terms in the regression models are commonly neglected, and the nonparametric bootstrap technique requires no assumption with regard to the distribution of the error term. Sonmez (2008) exemplifies that assuming a normal distribution for the error term becomes complicated when a few models are established as the normality assumption must be controlled for each estimation model. An average expected value of zero for the error term does not mean that there is not a measurement for the accuracy of the models derived from bootstrapping. Each model is checked from the point of the goodness of fit by using the mentioned indicators. If the estimated linear models are not adequate, higher order models or neural network models can be developed by integrating with bootstrap methods (Sonmez, 2008).

3.4 Empirical Cumulative Probability Distributions

Probability is the likelihood of occurrence of a situation, and it can be classified as theoretical or empirical. The empirical probability helps to determine the possibility of occurrence by using the previous examinations and experiments.

Cai (2013) states that the empirical cumulative probability distribution (ECPD) is a nonparametric function that assigns a probability rate of 1/n to each of n examinations in a sample. He explains that the data is ordered from smallest to largest in value to establish an ECPD, and the sum of the assigned probabilities are calculated up to each datum. The function of ECPD is generally denoted by $\hat{F}_n(x)$ or $\hat{P}_n(X \leq x)$, and it is defined as follows:

$$\hat{F}_n(x) = \hat{P}_n(X \leq x) = \frac{\sum_{i=1}^{n} I(x_i \leq x)}{n} \tag{23}$$

Where;

i : Index of summation

n : Total number of data

$$I(x_i \le x) = \begin{cases} 1, \text{when } x_i \le x \\ 0, \text{when } x_i > x \end{cases} \quad \text{: The indicator function}$$

In this study, the developed decision support tool obtains 100 different data samples by bootstrapping, and it establishes 100 regression models based on the obtained data samples and then it makes 100 predictions about the contingency rates of each of the projects in the portfolio by using regression models. Now, the decision support tool is used for an example project, and the made predictions about the contingency rate of this project are used in order to illustrate ECPD as shown in Figure 10.

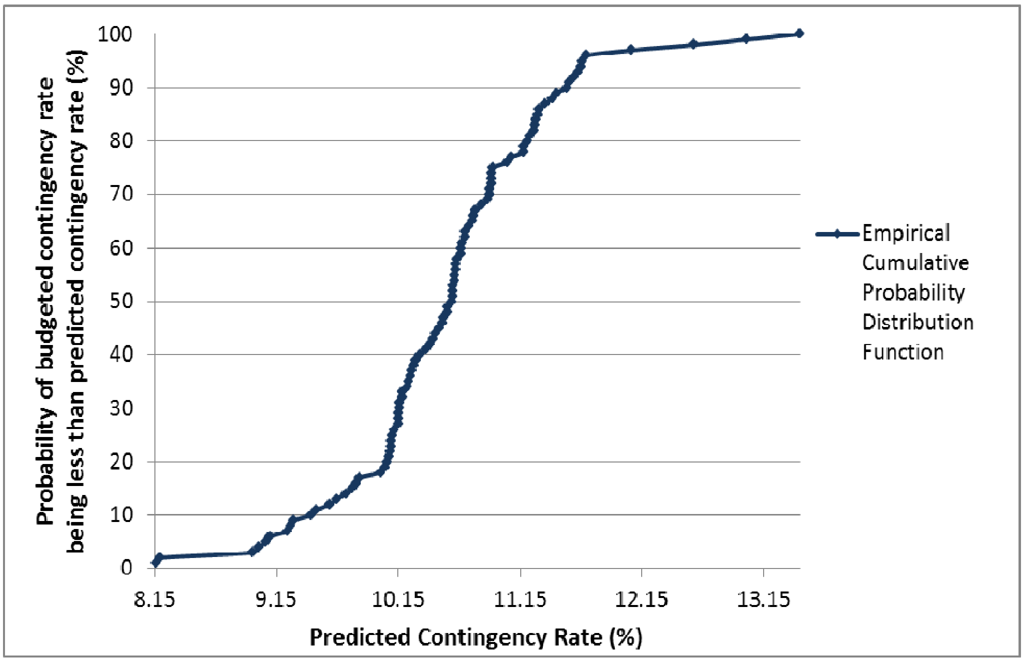

Figure 10: An ECPD Function for the Predicted Contingency Rate

CHAPTER 4

MODELLING METHODOLOGY

4.1 An Overview of the Developed Model

Risk-return relationship has been studied in many researches, yet there are very few researches on contingency-profit relationship of construction projects. In addition, most of the studies have been focused on a single project's contingency rate, but contingency analyzes for portfolios of construction projects are very few. The developed model aims to fill the explained gap in contingency-profit evaluation for international construction portfolios of projects. The developed decision support tool will also show how far estimated contingency and profit ratios are away from the experimental trend line of the contingency-profit relationship.

4.2 Background of Modelling

Data of construction projects that is used in contingency-profit analysis, determining the initial regression model, and initial contingency-profit curve will be explained under this title. The given information will help to understand the logic of the developed decision support tool.

4.2.1 Data of Construction Projects

Data of international construction projects obtained by Ergin (2005) is used as a base data in our developed model. He collected data of 26 international construction projects by making a questionnaire consists of two parts. In the first part of the questionnaire, international construction companies answered some questions about the company's age, size, experience, the contract type, and some contractual clauses. There are some questions about the country's political and economic conditions, construction market conditions, and the project in the second part of the questionnaire. The factors that are considered to have important effect on contingency estimation are evaluated by using the data obtained from the questionnaires.

Not all of the questions related with contingency estimation are answered in the questionnaires, and there is missing information in the results of questionnaires. Therefore, 24 of 26 projects are used for contingency-profit analysis in our decision support tool. Data of construction projects is summarized in Table 1.

Table 1: Data of Construction Projects

Project #	Advance Payment Rate (%)	Contract Type	Question about material availability	100/CRR	Country
1	10.00	Unit Price	4	1.46	Syria
2	0.00	Unit Price	2	1.69	Lebanon
3	10.00	Lump Sum	1	1.33	Poland
4	10.00	Lump Sum	2	1.21	Dubai
5	15.00	Unit Price	4	1.36	Kazakhistan
6	15.00	Unit Price	4	1.39	Romania
7	15.00	Unit Price	4	1.36	Uzbekistan
8	0.00	Lump Sum	3	1.27	Qatar
9	10.00	Unit Price	3	1.42	Bulgaria
10	10.00	Unit Price	3	1.42	Bulgaria
11	10.00	Unit Price	3	1.57	Pakistan
12	10.00	Unit Price	4	1.39	Ukraine
13	10.00	Unit Price	2	1.31	Russia
14	10.00	Unit Price	3	1.36	Tunisia
15	10.00	Unit Price	4	1.37	Turkmenistan
16	15.00	Unit Price	2	1.38	Tajikistan
17	10.00	Unit Price	3	1.36	Uzbekistan
18	20.00	Unit Price	5	1.38	Tajikistan
19	15.00	Unit Price	5	1.54	Tajikistan
20	5.00	Lump Sum	3	1.16	Ireland
21	10.00	Unit Price	2	1.22	Germany
22	10.00	Lump Sum	2	1.31	Russia
23	0.00	Lump Sum	5	2.60	Afghanistan
24	15.00	Lump Sum	4	1.37	Jordan

4.2.2 Determining Initial Regression Model

Ergin (2005) used regression analysis to estimate a contingency rate, and he conducted a correlation analysis to identify the factors that will be included in initial regression model. He used Pearson’s correlation method, and calculated coefficients of the variables obtained from the questionnaires and the country risk ratings (CRR) obtained from International Country Risk Guides (ICRG) by using Statistical Package for the Social Sciences (SPSS). Pearson's correlation coefficient (r) is calculated for a data set with two variables, x and y, as follows:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \times \sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{24}$$

Where;

i : Index of summation

n : Total number of data

$\bar{x}$: Average value of the variable x

$\bar{y}$: Average value of the variable y

He found that the contingency amount has a significant correlation with 14 variables, which are listed below, according to the results of Pearson's correlation analysis.

1. Country risk rating
2. Advance payment amount
3. Type of contract (Unit Price or Lump Sum)
4. Frequent changes in law and orders
5. Condition of the labor laws in the country related to contractors workforce
6. Street violence or civil war

7. Availability of material in the local market providing the desired quality and properties

8. Problems about stating the responsibility of the each partner in joint venture or consortium agreements

9. Contractual clauses about safety and environmental conditions

10. Possibility to finish the project on time

11. Level of congestion at site

12. Security conditions in the site

13. Attitude of the people living in the country to foreigners

14. Level of preparation for the tender

In his study, initial regression model has 14 independent variables and a dependent variable as contingency. He used the backward elimination in which a variable is deleted at every backward step in order to determine final regression model. Independent variables were eliminated starting from the initial regression equation depending on significance of the F test value. In the backward elimination method, the lowest F test value is compared with the predetermined critical F value. If the F test value is smaller than the predetermined critical F value, then the independent variable is eliminated from the model, and regression analysis is performed again. The F test statistic of the each variable existing in the model is calculated as follows:

$$F_{\text{test i}} = \left(\frac{\beta_i^2}{S_{\beta_i}^2}\right) \tag{25}$$

Where;

$F_{\text{test i}}$: F test value of the variable i

i : Index of the variables

β_i : Coefficient of the variable i in the examined model

S_{β_i} : Standard error of the variable i

Finally, Ergin (2005) observed that all F test values of the variables were higher than the F critical value, and he determined the final regression model with 4 independent variables, which are listed below, and a dependent variable as contingency.

1. Country risk rating
2. Advance payment amount
3. Type of contract
4. Question 24 in the second part of his questionnaire

In our tool, the explained findings of the study done by Ergin (2005) are used, and the regression model with 4 independent variables is established as indicated below:

$$y = \beta_0 + \beta_1 \times x_1 + \beta_2 \times x_2 + \beta_3 \times x_3 + \beta_4 \times x_4 \tag{26}$$

Where;

y : Contingency rate (% of the contract price)

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$: Regression coefficients

x_1 : Advance payment rate (% of the contract price)

$x_2 = \begin{cases} 0, \text{Unit Price} \\ 1, \text{Lump Sum} \end{cases}$: Contract type

$x_3 = \begin{cases} 1, \text{Strongly Disagree} \\ 2, \text{Disagree} \\ 3, \text{Neutral} \\ 4, \text{Agree} \\ 5, \text{Strongly Agree} \end{cases}$: The possibility to be able to procure the materials with desired quality and feature in the country where the project will be carried out is quite low. (Question 24 in the second part of the questionnaire)

$x_4 = \frac{100}{\text{CRR}}$: Country risk rating (CRR is between 1 and 100.)

4.2.3 Initial Contingency-Profit Curve

Being inspired by the concept of efficient frontier in MPT, a new concept named normal contingency-profit curve is proposed in this study. Profit rates of projects will be used as a measure of profitability instead of expected returns of investments, and risk will be evaluated by considering contingency ratios instead of standard deviation. Normal contingency-profit curve provides normal contingency-profit values not optimal values such in efficient frontier.

As mentioned before, there is data of 24 construction projects, but 17 of 24 projects have the profit rate information. Therefore, initial contingency-profit curve is obtained by fitting a function to data of 17 projects.

Initially, a linear function is fit to data of construction projects as shown in Figure 11 by using Excel's feature of assigning a trend line to data. A function with an equation of $y = 0.8428x + 7.7169$ is assigned to data, and the coefficient of determination (R^2) is calculated as 0.51 for the approximated linear function.

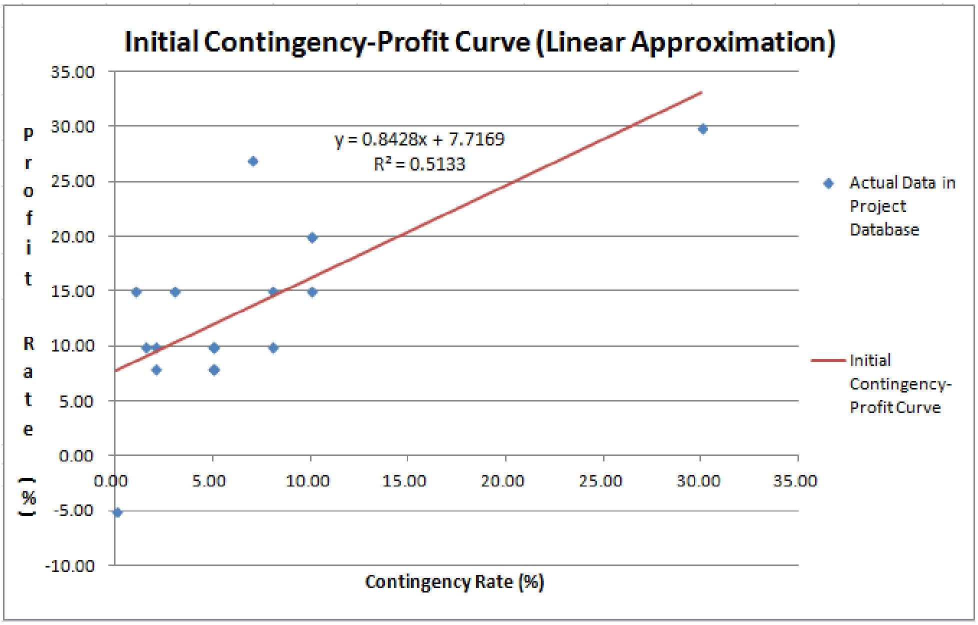

Figure 11: Initial Contingency-Profit Curve (Linear Approximation)

Later, a second order polynomial function is fit to data of construction projects as shown in Figure 12. A function with an equation of $y = -0.0241x^2 +$

$1.5484x + 5.1732$ is assigned to data, and the coefficient of determination (R^2) is calculated as 0.56 for the approximated polynomial function.

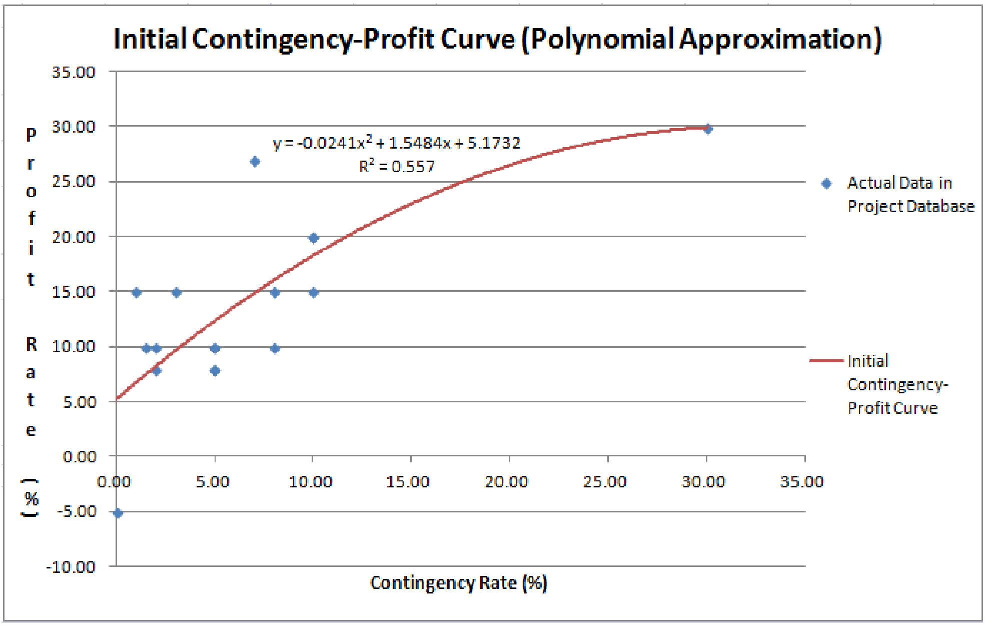

Figure 12: Initial Contingency-Profit Curve (Polynomial Approximation)

Linear approximation for contingency-profit relationship is not very realistic due to the fact that profit rate is not expected to increase linearly in response to increasing contingency rate. Comparing R^2 values of two approximations, second order polynomial approximation, which has a higher R^2 value, provides a fit with higher quality. In addition, second order approximation shows a logical contingency-profit relationship for historical data. Further, higher order approximations are not preferred in this study, because higher order function starts to oscillate, and the contingency-profit curve becomes unrealistic and impractical. As a result, second order polynomial function is selected in order to evaluate contingency-profit relationships of construction portfolios.

After determining the normal contingency-profit curve, the graph is divided into four different regions as illustrated in Figure 13. Average contingency rate is calculated as 6.62% by using historical project data. Area on the left side of the average contingency rate line is considered as low risk region, and region on the right side of the average contingency rate line is considered as high risk region. In addition, area above the normal contingency-profit curve is evaluated as high profit region, and area below the normal contingency-profit curve is evaluated as low profit region.

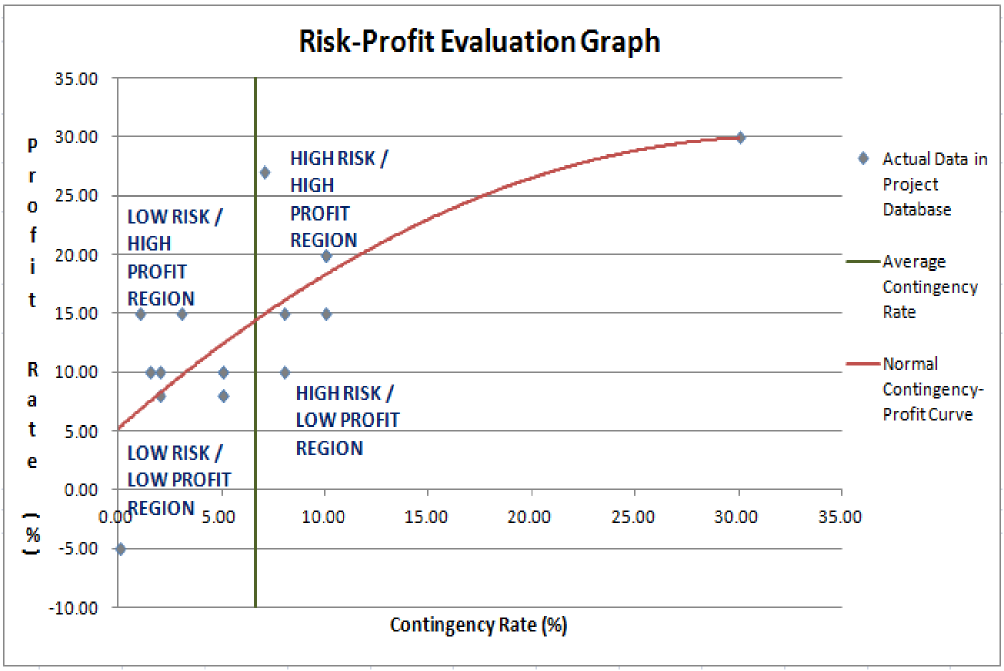

Figure 13: Risk-Profit Evaluation Graph

Contractors can decide to have a portfolio located in any of regions proposed in Figure 13 due to private reasons. For instance, a contractor, which plans to enter a new market, could prefer a portfolio located in high risk / low profit region in order to win tenders in the new market. Moreover, a contractor can also decide to have a portfolio located in high risk / low profit region due to the fewness of projects carried out by the contractor. Further, a contractor, which conducts many projects simultaneously, can choose a portfolio located in high profit regions. The developed tool enables contractors to evaluate their portfolios in terms of contingency-profit relationship, and contractors can act according the result of the performed analysis during bidding stages.

CHAPTER 5

THE DECISION SUPPORT TOOL AND A MODEL APPLICATION

The tool is developed by using Analysis ToolPak – Visual Basic for Applications (VBA) and Solver Add-Ins in Excel. 16 different modules and 4 user forms are created to establish the tool in VBA Add-In. The developed tool offers two choices for users at the beginning. As shown in Figure 14, two choices are entering actual project data into the project database and performing contingency-profit analysis for planned projects.

In this study, a project database is created by using the project data collected by Ergin (2005), and data of 2 additional completed international construction projects is added to this project database. In consequence of data addition to the project database, the total number of international construction projects, which are used for contingency-profit analysis, is 26 in total, and the total number of projects with the knowledge of profit rates, which are used for drawing contingency-profit curve, is 19 in total. Entering actual project data and performing contingency-profit analysis will be explained with a model application in this chapter.

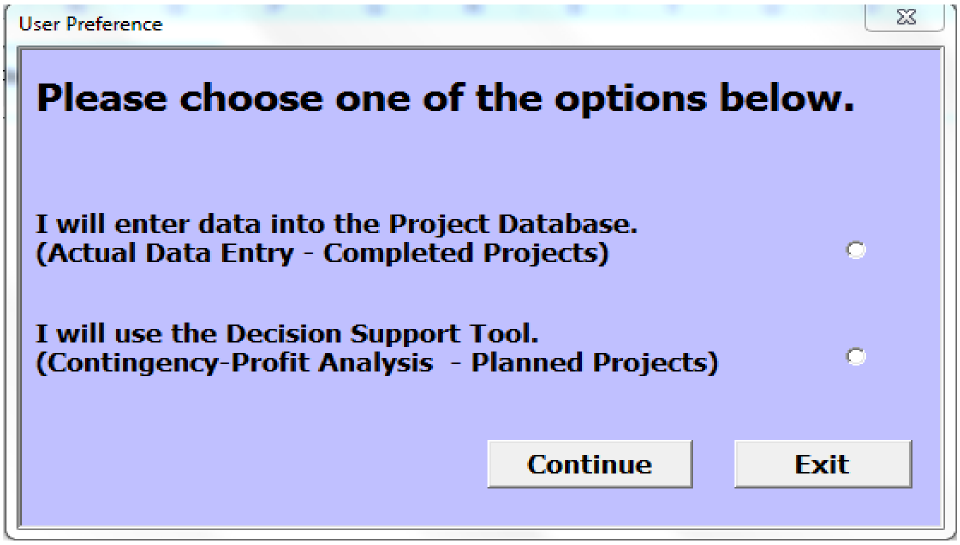

Figure 14: Options Offered by the Tool

5.1 Project Database and Actual Data Entry for Completed Projects

Contractors and investors have a chance to create their own project database by using this option of the developed tool. Data of completed projects can be entered into the project database in order to contribute to further analyzes. The user is asked to enter some information about the completed project, and given information is registered into the project database after filling in the form. The required information to complete data entry is listed below, and actual data entry form for completed projects is shown in Figure 15.

- Start year of the project: It is required to propose a CRR by extracting from ICRGs (The PRS Group, Inc., 2012 & 2013).

- Country: The tool lists 140 countries and an option of other to be selected. The country where the project was carried out is necessary to determine a CRR.

- Country risk rating: The tool proposes a CRR for the projects started in 2012 and 2013 by extracting from ICRGs (The PRS Group, Inc., 2012 & 2013). Moreover, the user can change the proposed CRR and enter a different CRR.

- Contract type: There are two alternatives for contract type: 0 – Unit Price and 1 – Lump Sum.

- Advance payment rate: The user is asked to enter the advance payment rate as percentage of the contract price.

- Question about material availability: The tool asks a question that is required for contingency estimation, and the user answers this question by using a 1-5 scale.

- Contingency rate: It is entered as percentage of the contract price, and it is necessary for contingency estimation process.

- Profit rate: It is used to draw contingency-profit curve, and it is entered as percentage of the contract price.

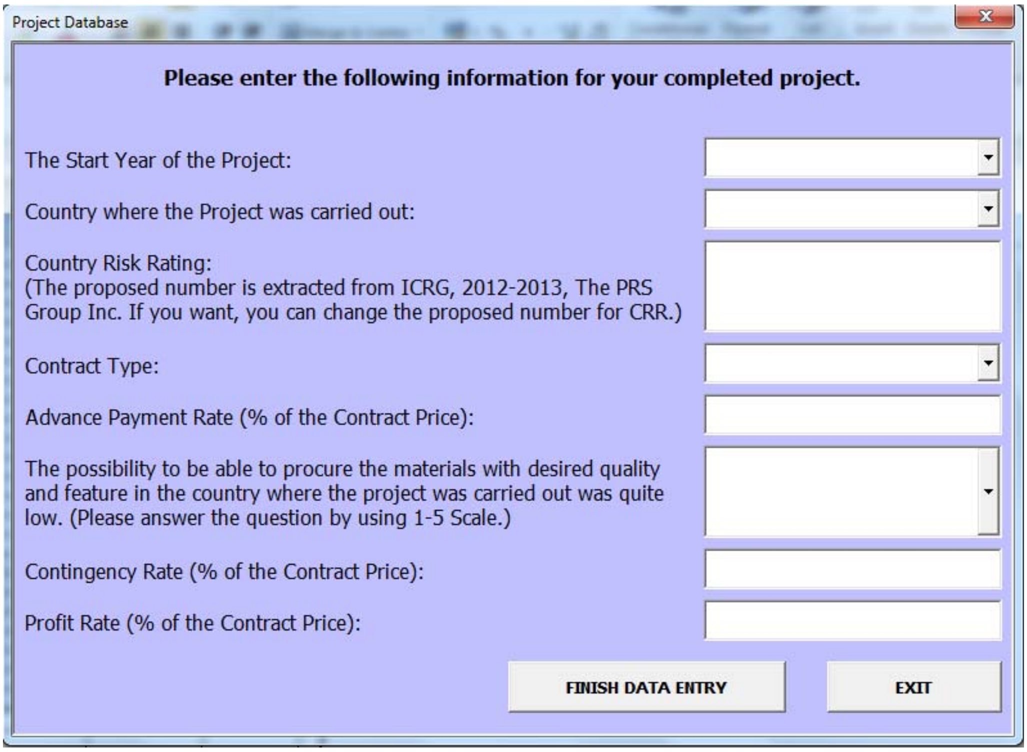

Figure 15: Actual Data Entry Form for Completed Projects

In our model application, data of two additional completed international construction projects is entered into the project database. These projects were carried out in Afghanistan and Turkmenistan between the years of 2010 and 2012. After completion of data entry, 26 projects are available in the project database, and these projects will be used for contingency-profit analysis for planned portfolio of projects. Data of 26 construction projects is summarized in Table 2.

Table 2: Updated Project Database

Project #	Advance Payment Rate (%)	Contract Type	Question about material availability	100/CRR	Country
1	10.00	Unit Price	4	1.46	Syria
2	0.00	Unit Price	2	1.69	Lebanon
3	10.00	Lump Sum	1	1.33	Poland
4	10.00	Lump Sum	2	1.21	Dubai
5	15.00	Unit Price	4	1.36	Kazakhistan
6	15.00	Unit Price	4	1.39	Romania
7	15.00	Unit Price	4	1.36	Uzbekistan
8	0.00	Lump Sum	3	1.27	Qatar
9	10.00	Unit Price	3	1.42	Bulgaria
10	10.00	Unit Price	3	1.42	Bulgaria
11	10.00	Unit Price	3	1.57	Pakistan
12	10.00	Unit Price	4	1.39	Ukraine
13	10.00	Unit Price	2	1.31	Russia
14	10.00	Unit Price	3	1.36	Tunisia
15	10.00	Unit Price	4	1.37	Turkmenistan
16	15.00	Unit Price	2	1.38	Tajikistan
17	10.00	Unit Price	3	1.36	Uzbekistan
18	20.00	Unit Price	5	1.38	Tajikistan
19	15.00	Unit Price	5	1.54	Tajikistan
20	5.00	Lump Sum	3	1.16	Ireland
21	10.00	Unit Price	2	1.22	Germany
22	10.00	Lump Sum	2	1.31	Russia
23	0.00	Lump Sum	5	2.60	Afghanistan
24	15.00	Lump Sum	4	1.37	Jordan
25	4.36	Lump Sum	5	1.79	Afghanistan
26	20.00	Lump Sum	5	1.67	Turkmenistan

5.1.1 Updated Contingency-Profit Curve

Initial contingency-profit curve was obtained by fitting a polynomial function to data of 17 completed projects. After completion of data entry for 2 additional completed projects, 19 construction projects have the profit rate information, and the obtained normal contingency-profit curve is updated according to the entered project data.

Initially, a linear function is fit to data of 19 construction projects as shown in Figure 16 by using Excel's feature of assigning a trend line to data. A function with an equation of $y = 0.8467x + 7.8467$ is assigned to data, and the coefficient of determination (R^2) is calculated as 0.48 for the approximated linear function.

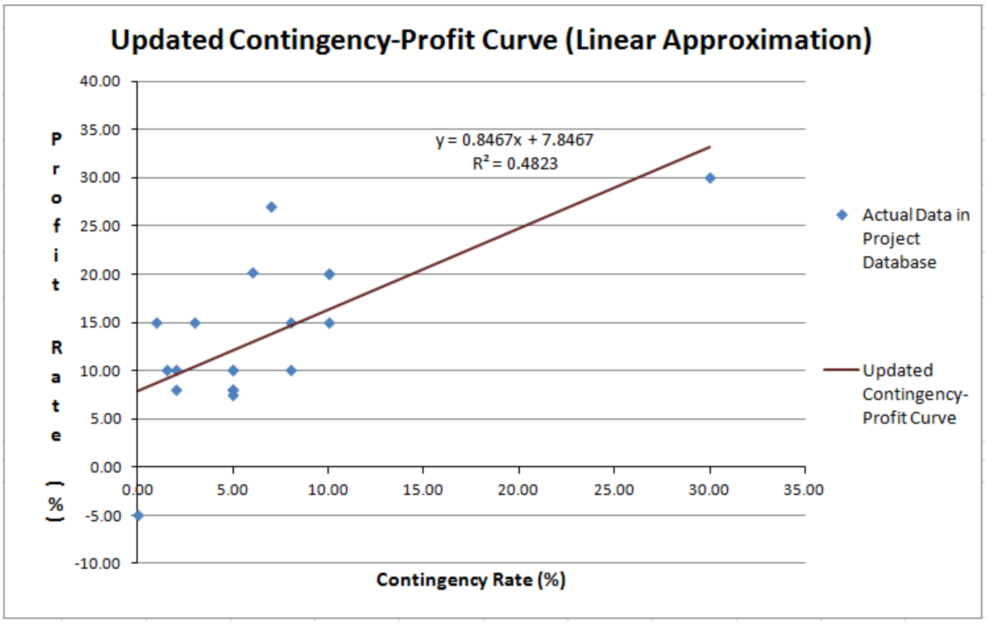

Figure 16: Updated Contingency-Profit Curve (Linear Approximation)

Later, a second order polynomial function is fit to data of 19 construction projects as shown in Figure 17. A function with an equation of $y = -0.026x^2 + 1.6068x + 5.0349$ is assigned to data, and the coefficient of determination (R^2) is calculated as 0.53 for the approximated polynomial function.

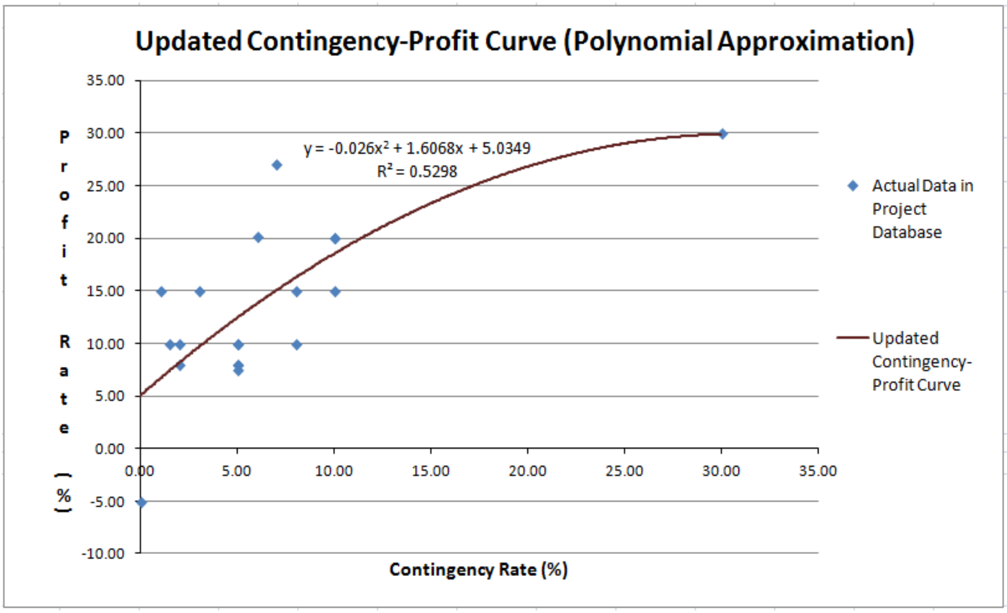

Figure 17: Updated Contingency-Profit Curve (Polynomial Approximation)

Comparing R^2 values of two updated approximations, second order polynomial approximation, which has a higher R^2 value, provides a fit with higher quality. After updating the normal contingency-profit curve, the risk-profit evaluation graph is also updated as shown in Figure 18. After data entry for 2 additional completed projects, average contingency rate is calculated as 6.50% by using historical project data. The updated risk-profit evaluation graph will be used to analyze condition of the planned portfolio. Data pair of portfolio will be displayed on this graph, and the user will see in which region the planned portfolio is located.

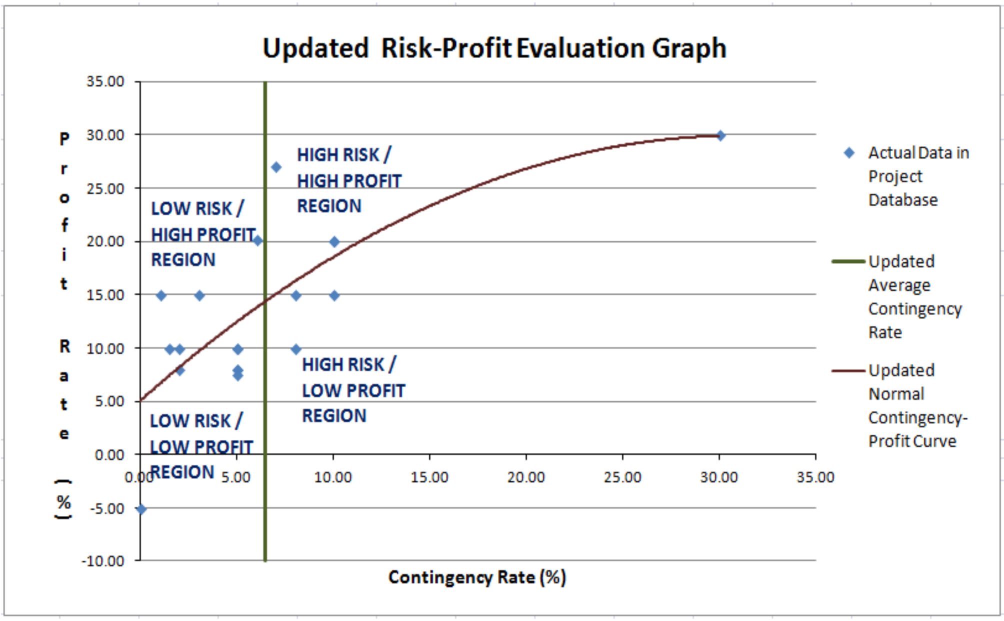

Figure 18: Updated Risk-Profit Evaluation Graph

5.2 Decision Support Tool for Planned Projects

Second option of the tool is the decision support tool that performs portfolio contingency-profit analysis. The tool enables users to analyze their portfolios in comparison to the normal contingency-profit curve that is obtained from historical data. In addition, the tool displays condition of the planned portfolio on risk-profit evaluation graph that proposes four different regions for risk-profit relationship. Moreover, the tool provides a range for portfolio contingency-profit data pair, and the users have chance to evaluate their portfolios in the worst and best cases. Phases of this analysis will be explained by performing a model application for 2 international construction projects that will be carried out in Turkmenistan and Iraq. Registered data of 26 projects in the project database will be used in order to make portfolio contingency-profit analysis.

5.2.1 Data Samples Obtained by Bootstrapping

The first phase of the contingency-profit analysis is obtaining data samples by bootstrapping. The tool creates 100 data samples with a size of 26 projects by resampling data from the project database. Moreover, values of all variables, which are contingency rates, advance payment rates, contract types, answers to the question about material availability, and country risk ratings, are written next to the project numbers in an Excel sheet. As mentioned under the title of bootstrap method on regression models, the bootstrap data sets include members of the original data set, and it differs between the bootstrap data sets how many times each of the original members is appeared. The tool creates an extensive table for data samples obtained by bootstrapping, and a filtered version of this table is provided in Table 3 to demonstrate sampling.

Table 3: A Filtered Table of Data Samples Obtained by Bootstrapping

	Sample #1	Sample #2	Sample #3	...	Sample #98	Sample #99	Sample #100
Data #	Project #	Project #	Project #	...	Project #	Project #	Project #
1	1	11	20	…	6	11	26
2	7	3	3	…	24	23	13
3	9	18	22	…	1	15	14
4	8	4	20	…	23	11	6
5	4	8	17	…	7	14	25
6	15	16	9	…	5	26	1
7	5	10	19	…	25	23	23
8	15	4	22	…	12	13	22
9	2	26	17	…	3	20	15
10	5	22	26	…	24	1	2
11	18	10	18	…	5	11	7
12	10	9	18	…	7	1	17
13	11	16	1	…	10	15	15
14	3	16	11	…	17	24	17
15	8	14	24	…	16	21	9
16	2	20	3	…	22	9	9
17	8	5	5	…	22	11	2
18	21	17	13	…	2	6	6
19	8	10	24	…	10	13	22
20	4	14	11	…	5	12	6
21	14	6	2	…	19	24	21
22	4	2	10	…	16	9	20
23	3	18	15	…	7	11	16
24	7	20	14	…	13	20	13
25	2	7	3	…	14	5	7
26	23	3	13	…	24	15	14

5.2.2 Performing Regression Analysis

The second stage of the contingency-profit analysis is performing regression analysis. The tool uses the obtained bootstrap samples, each of which contains 26 projects, in order to perform regression analysis. For each of the determined samples, regression coefficients are calculated by using the least squares method as formulized in Formula 17. After calculation of the regression coefficients, the tool establishes 100 different regression models, each of which consists of a dependent variable and four independent variables, as indicated in

Formula 26. Moreover, the tool checks the goodness of fit for each of the established model by using the indicator of the coefficient of determination (R^2) as formulized in Formula 21. The tool calculated R^2 values between 0.78 and 0.94 for our model application. Considering that close R^2 values to 1 indicate a better fit, the calculated R^2 values are efficient, and there is no necessity of higher order regression models. The tool keeps the regression coefficients and R^2 values in an Excel sheet, and a filtered version of this sheet is provided in Table 4 to visualize the performed analysis.

Table 4: Regression Coefficients and R^2 values

Model #:	**1**	**2**	**3**	**…**	**98**	**99**	**100**
Regression Coefficients:	ßi	ßi	ßi	…	ßi	ßi	ßi
$ß_0$	-15.9188	-2.97857	-4.51452	…	-23.463	-9.8018	-15.2126
$ß_1$	-0.361883	-0.3398	-0.36645	…	0.18013	-0.60983	-0.05383
$ß_2$	3.699788	2.38238	4.33908	…	2.79209	4.99061	4.15592
$ß_3$	1.97826	1.49039	1.91081	…	0.2156	2.29763	-0.84714
$ß_4$	12.45557	4.52197	4.44455	…	18.2406	8.51633	15.9281

Model #:	**1**	**2**	**3**	**…**	**98**	**99**	**100**
The Coeff. of Determin.:	R^2	R^2	R^2	…	R^2	R^2	R^2
	0.93999	0.86671	0.7853	…	0.78302	0.78529	0.78528

Min R^2:	0.77744
Max R^2:	0.93999

5.2.3 Data Entry for the Planned Portfolio of Projects

After establishing 100 different regression models, data entry for the planned portfolio of projects is required to perform the analysis. Initially, the user is expected to select the number of projects in the planned portfolio as shown in Figure 19. The decision support tool enables contractors and investors to analyze portfolios that contain up to 1000 projects. The planned portfolio contains 2 international construction projects in our model application, so the number of projects in the portfolio is selected as 2, and the command button named as next is clicked.

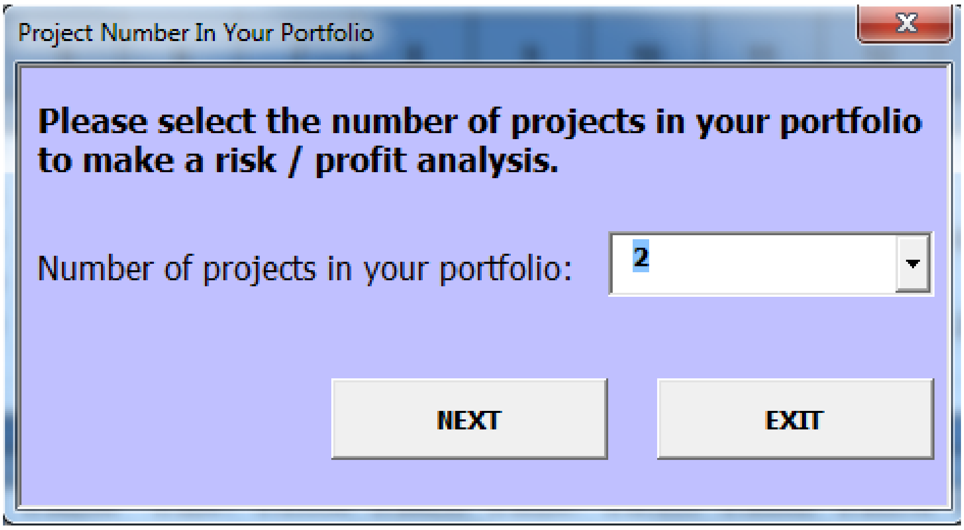

Figure 19: Selecting Number of Projects in the Portfolio

Then, the user is asked to enter some information about the first project in the portfolio, and given information is kept in a separate Excel sheet after filling in the form. The required information to complete data entry is listed below, and data entry form for planned projects is shown in Figure 20.

- Country: The first project in our portfolio is planned to be constructed in Turkmenistan, and other option is selected from the country list. The country where the project will be carried out is necessary to determine a CRR.

- Country risk rating: The tool proposes an approximate CRR by extracting from ICRG 2013 (The PRS Group, Inc., 2013). Moreover, the user can change the proposed CRR and enter a current CRR.

- Contract type: The options are unit price and lump sum. Contract type is an independent variable in the determined regression model that affects contingency estimation.

- Advance payment rate: It is another independent variable in the determined regression model, and the advance payment rate is entered as percentage of the contract price.

- Question about material availability: The tool asks a question that is a factor affecting contingency estimation, and this question is answered by using a 1-5 scale.

- Probability percentage: The user is asked to enter a percentage that indicates the probability of budgeted contingency rate being less than predicted contingency rate. This percentage will be used in estimating contingency rate from the obtained ECPD. High probability percentages will result in high contingency rates, and the user will be on the safe side, but competitiveness of the bid will be decreased.

- Total contract price: It is required to calculate the portfolio contingency and profit rates in direct proportion to the given project contract prices. Total contract price is entered in United State Dollar (USD).

- Profit rate: It is necessary to calculate the portfolio profit rate, and the calculated portfolio profit rate will be shown on the contingency-profit graph. It is entered as percentage of the contract price.

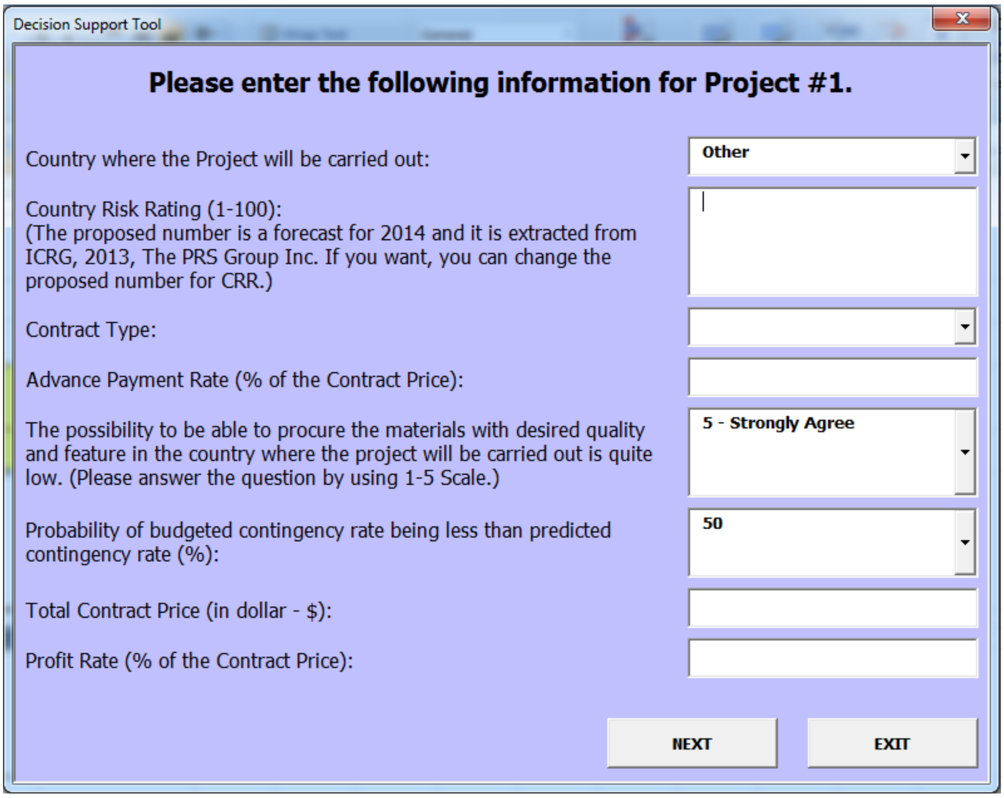

Figure 20: Data Entry Form for Project #1

After completion of data entry for the first project, the tool displays the data entry form for the second project in the portfolio (Figure 21). Data entry for the second project is identical with data entry for the first project. The required information to complete data entry was explained above. The second project in our portfolio is planned to be constructed in Iraq, and the country is selected from the country list. The remaining data is entered as it is explained for the previous project. As shown in Figure 21, the tool disables selecting a probability of budgeted contingency rate being less than predicted contingency rate for the second project, and the selected probability percentage for the first project, which is 50% in our model application, is used for all of the projects in the portfolio. By using the same probability percentage for all projects, contingency rates of all projects are determined from the obtained ECPD at the same confidence level.

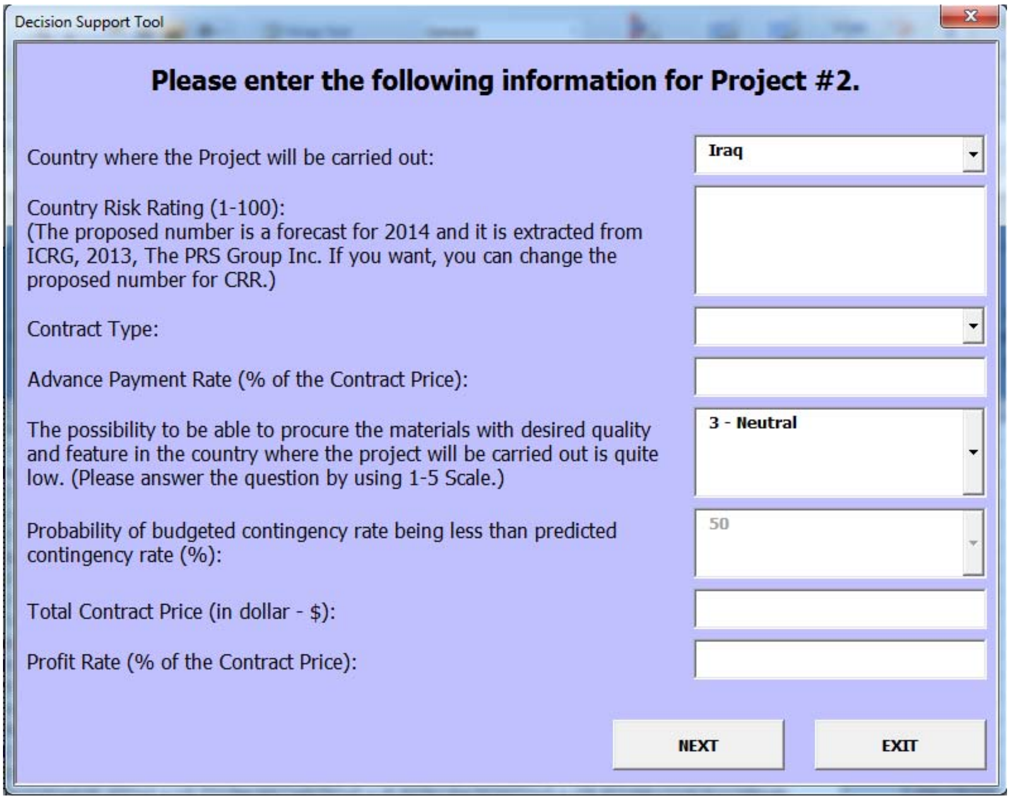

Figure 21: Data Entry Form for Project #2

5.2.4 Portfolio Contingency-Profit Analysis and Results

After completion of data entry for all projects in the portfolio, contingency-profit analysis is performed for the planned portfolio. The decision support tool estimates 100 different contingency rates for each of the projects by using the established regression models and entered information. These estimations are ordered from smallest to largest in value, and an empirical cumulative probability distribution is obtained. By using the probability of budgeted contingency rate being less than the predicted contingency rate, which is selected as 50% in our model application, point contingency estimates for each of the projects are determined from the obtained ECPD. Project profit rates are entered by the user as it is explained under the previous title. Later, portfolio contingency rate (cr_p) and portfolio profit rate (pr_p) are calculated in direct proportion to the project contract prices by using Formulas 27 and 28, and both of these rates are indicated as percentages of the total portfolio price.

$$cr_p = \frac{\sum_{i=1}^{n}(\text{Project Contract Price})_i \text{ x } (\text{Project Contingency Rate})_i}{\sum_{i=1}^{n}(\text{Project Contract Price})_i} \tag{27}$$

$$pr_p = \frac{\sum_{i=1}^{n}(\text{Project Contract Price})_i \text{ x } (\text{Project Profit Rate})_i}{\sum_{i=1}^{n}(\text{Project Contract Price})_i} \tag{28}$$

Where;

i : Index of summation

n : Total number of projects in the portfolio

$\sum_{i=1}^{n}(\text{Project Contract Price})_i$: Total portfolio price

As a result, portfolio contingency rate is estimated as 9.37%, and portfolio profit rate is calculated as 9.94% for our model application. Finally, the determined data pair of rates is shown on the risk-profit evaluation graph, which is obtained from the actual data registered in the project database, as shown in Figure 22. According to the analysis result, the sample portfolio is located in high risk / low profit region. According to the location of the planned portfolio, contractors can change their profit rates, and they can decide on the portfolio's risk-profit region. Further discussions about the analysis result will be provided under the title of discussions about the result of the model application.

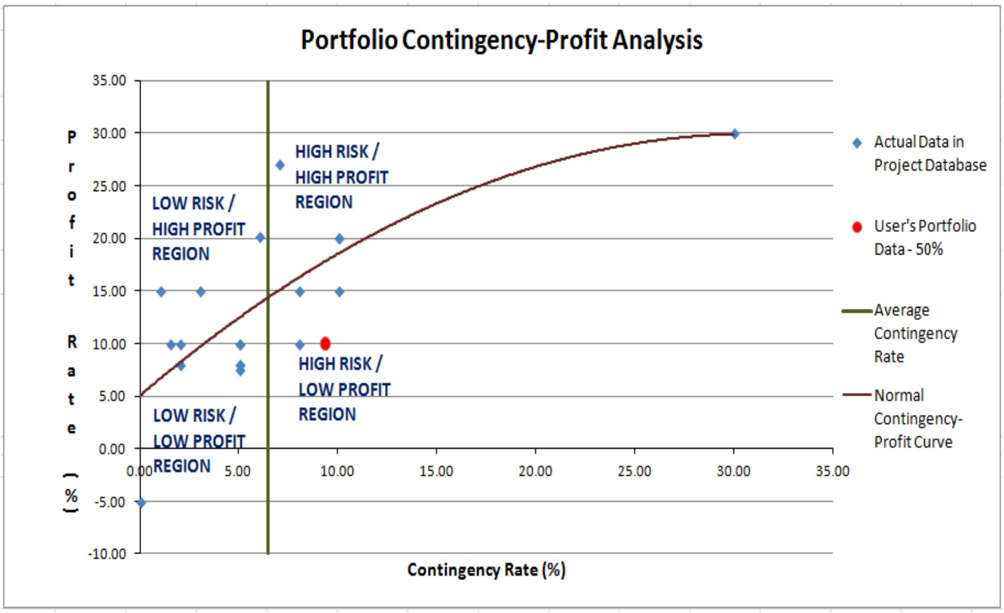

Figure 22: Portfolio Contingency-Profit Analysis Result

5.2.5 Range Estimation for Portfolio Contingency Rate

Another feature of the improved tool is that it enables users to obtain a range for portfolio contingency rate estimation, and users can evaluate their portfolios for the worst, normal, and the best cases. Portfolio contingency estimation for probability of 5% is assumed to be the best case in which impacts of risks and uncertainties are covered with a small amount of contingency. Use of 95% probability rate is assumed to be the worst case in which high amount of contingency is used to cover all possible impacts of risks and uncertainties.

In the performed model application, normal scenario with a probability of 50% was examined. By using the obtained ECPD in the model application, the best scenario with a probability of 5% and the worst scenario with a probability of 95% are also examined in this thesis. By using three different probabilities of budgeted contingency rate being less than the predicted contingency rate, point contingency estimates for each of the projects are determined from the obtained ECPD. Next, portfolio contingency rate and portfolio profit rate are calculated in direct proportion to the project contract prices by using Formulas 27 and 28. Portfolio contingency rates are estimated as 5.50%, 9.37%, and 15.32% for the probabilities of 5%, 50%, and 95% respectively. Finally, the estimated data pairs of rates are shown on the contingency-profit curve as shown in Figure 23.

As a result, portfolio contingency rate is estimated between 5.50% and 15.32% for the model application, and the tool shows conditions of the planned portfolio for different scenarios as illustrated in Figure 23. Investors and contractors can have position according to the displayed conditions, and they can improve their portfolio condition by changing the estimated project profit rates.

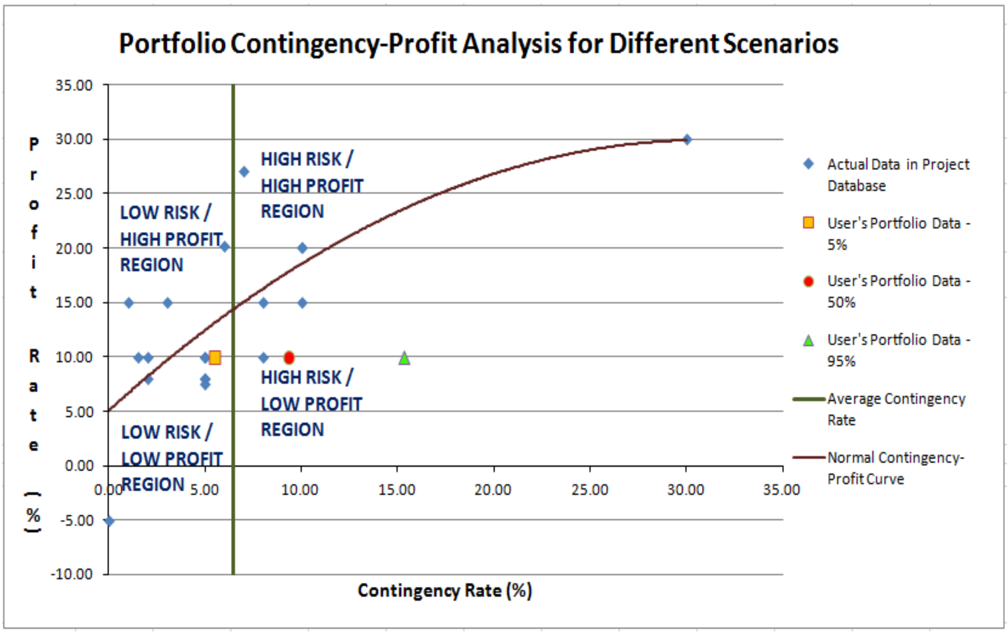

Figure 23: Portfolio Contingency-Profit Analysis for Different Scenarios

5.3 Discussions about the Result of the Model Application

According to the result of portfolio contingency-profit analysis (Figure 22), the sample portfolio is located in high risk / low profit region, and data pair of the model portfolio is not very close to the normal contingency-profit curve. The location of the sample portfolio is not very desirable under normal conditions, but the contractor can have some special reasons to continue with this portfolio. If the contractor has very few or no projects to be carried out, the contractor can accept a portfolio located in high risk / low profit region. Moreover, the contractor can enter a new market by choosing portfolios located in high risk / low profit region. In case of selecting a portfolio in this region, the contractor should give offers with high profit rates for next projects that are not risky and do not require high contingency rates.

If there is not a special reason such as mentioned ones, the contractor should take action to move to regions that are more efficient. The contractor can increase the estimated profit rates for projects in order to move high risk / high profit region or at least approach to the normal contingency-profit curve. It should be noted that increasing profit rates in high risk regions, in which high contingency rates are used, will result in high contract prices, and competitiveness of bids will be decreased.

Another result of the contingency-profit analysis performed by the developed tool is range estimation for portfolio contingency rate as shown in Figure 23. Portfolio contingency rate is estimated between 5.50% and 15.32% for the model application, and portfolio contingency rate is estimated as 9.37% for the normal scenario with a probability rate of 50%. It is observed that the estimated profit rate is low for the risky portfolio that requires high contingency rate. Moreover, portfolio contingency-profit analysis for different scenarios (Figure 23) shows that data pair of the planned portfolio is very ineffective for the worst scenario in which probability of budgeted contingency rate being less than the predicted contingency rate is 95%.

CHAPTER 6

CONCLUSION

6.1 Conclusion

Estimation of proper contingency and profit amounts is necessary for preventing cost overrun and holding the chance of winning the tender. Contingency and profit amounts are generally estimated based on experience and intuition, so they can not be evaluated in terms of efficiency by companies during bidding stage. In addition, most of the researchers have been studied contingency estimation for only a project, but many construction companies carry out several projects simultaneously. Contingency-profit analyzes for portfolios of projects are required to satisfy the need of construction sector. This study aims to fill the mentioned gaps in contingency-profit analysis for international construction portfolios of projects with the developed decision support tool. The decision support tool helps contractors and investors to have an idea about efficiencies of contingency and profit ratios that will be used in their portfolios, and condition of the planned portfolio is displayed on risk-profit evaluation graph that proposes four different risk-profit regions.

It is very common that contingency and profit amounts are traditionally estimated as a predetermined percentage of project base cost. Contractors commonly consider only a point estimate to determine contingency rate. Being aware of contingency rate range will help contractors to give the right decision. The improved tool provides a range for portfolio contingency rate, and it estimates portfolio contingency rate for the best, normal, and worst scenarios with probability rates of 5%, 50%, and 95% respectively. This feature allows evaluation for condition of the planned portfolio in different cases.

The developed tool in this study estimates contingency rate by using an integrated method that includes the advantages of using historical data, parametric methods, and probabilistic techniques simultaneously. Moreover, the developed tool does not require excessive mathematical equations and limiting assumptions. The decision support tool provides a simple and rapid way to perform contingency-profit analysis for portfolios of projects.

In the established project database, data of 26 international construction projects is available, and the contingency-profit curve was drawn by using 19 international projects with the knowledge of profit rates. The user has a chance to enter data of completed projects into the project database. As the number of the available data in the database increases, more accurate and realistic results can be obtained by using the developed decision support tool. Moreover, there are very few projects with high contingency rate in our project database, and this is a limitation of the normal contingency-profit curve.

The model application performed in this study showed that the planned portfolio could be located in undesirable risk-profit regions. Contractors could be aware of the portfolio situation by the help of the developed decision support tool. Contractors may decide to stay in the current region due to some reasons such as fewness of projects carried out by the contractor or entering a new market. Contractors may also decide to move toward more desirable risk-profit regions by changing their estimated profit rates. The developed decision support tool enables the user to take action in advance to eliminate the possible impacts of inefficient estimations.

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