VALUE-BASED RISK MANAGEMENT IN DEFENSE PROJECTS PRICING WITH A ROBUST OPTIMIZATION APPROACH

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ABSTRACT

VALUE-BASED RISK MANAGEMENT IN DEFENSE PROJECTS PRICING WITH A ROBUST OPTIMIZATION APPROACH

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In this study, we address the bid pricing problem of a defense company facing with supply chain and financial risks due to long-term project planning. Creating shareholder value has become a quite popular topic in business as value-adding companies are the only ones to survive in the market. We formulate the problem as a value-based performance and risk management model through robust optimization approach in order to cope with various ambiguities over project lifecycle with possible discrete scenario set. Several project attributes identified as having critical importance for the company are employed in the bid pricing problem objective function using a multi-attribute utility function. The aim of our model is then to obtain the maximum weighted utility for a project with the related risk factor and probability of winning so as to use our solution methodology as a decision support tool in the bidding operations of the company.

In our formulation, the bid pricing problem is treated as a problem of value creation for the shareholders under a risky environment. We therefore propose an approach to find the optimal bid price which will maximize the total utility gain by combining integrated risk factors and probability of winning, while maximizing shareholder wealth under uncertain conditions in the total utility function as well. Since probability of winning and a winning bid price value create a trade-off for the bid for the company, our robust approach aims to find the best possible bid price by considering this trade-off while refraining from possible financial losses.

Keywords: Robust Optimization, Project Bid Pricing, Value-Based Performance and Risk Management, Economic Value Added, Multi-Attribute Utility

ÖZ

GÜRBÜZ OPTİMİZASYON YAKLAŞIMIYLA SAVUNMA PROJELERİ FİYATLANDIRMASINDA DEĞER-ODAKLI RİSK YÖNETİMİ

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Bu çalışmada, bir savunma sanayii firmasının uzun süreli proje planlamasına bağlı olarak tedarik zinciri risklerine ve finansal risklere maruz kalan teklif fiyatlandırma problemini ele almaktayız. Piyasada sadece değer yaratan firmalar ayakta kalmayı başarabildiğinden, pay sahiplerine düşen değerin artırılması konusu oldukça popüler hale gelmiştir. Bu hususu dikkate alarak, teklif fiyatlandırma problemini proje yaşam döngüsü boyunca görülebilecek çeşitli belirsizliklerin ortadan kaldırılması amacıyla ve gürbüz optimizasyon yaklaşımı doğrultusunda olası farklı senaryo setleriyle, değer-odaklı performans ve risk yönetimi modeli olarak formüle etmekteyiz. Bu kapsamda, teklif fiyatlandırma problem amaç fonksiyonunda firma için kritik öneme sahip olan çeşitli proje özellikleri, çok-nitelikli fayda fonksiyonu kullanılarak dikkate alınmaktadır. Modelimizin amacı, bir proje kapsamında ilgili risk faktörü ve kazanma olasılığını hesaba katarak en yüksek ağırlıklı faydayı bulmak ve firmanın tekliflendirme süreçlerinde karar destek aracı olarak kullanabilecek bir çözüm metodolojisi elde etmektir.

Formülasyonumuzda, teklif fiyatlandırma problemi riskli bir çevrede pay sahipleri için değer yaratma problem olarak ele alınmaktadır. Biz, bu nedenle, toplam fayda fonksiyonundaki pay sahipleri kazanımını belirsiz şartlar altında maksimize ederken, toplam fayda kazanımını entegre risk faktörleri ve kazanma olasılığı ile kombine ederek maksimize edecek bir yaklaşım önermekteyiz. Kazanma olasılığı ve kazanacak teklif fiyatı değeri firma için bir ödünleşme yarattığından, gürbüz optimizasyon yaklaşımımız bu ödünleşmeyi hesaba katarak, olası finansal kayıplardan korunurken mümkün olan en iyi tekli fiyatını bulmayı amaçlamaktadır.

Anahtar Kelimeler: Gürbüz Optimizasyon, Proje Teklif Fiyatlandırma, Değer-Bazlı Performans ve Risk Yönetimi, Ekonomik Katma Değer, Çok-Nitelikli Fayda

To my family

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CHAPTER 1

INTRODUCTION

In the defense sector, operations are mainly based on project related activities, and project lifecycles are relatively longer compared to other sectors, particularly much longer for R&D projects. Due to long-term projects, uncertainties and their effects on the profitability of the company are needed to be considered in detail in terms of project management. Main risk types commonly encountered in defense projects are technical risks, logistics risks and financial risks.

The company subject to this thesis is one of the pioneers in Turkish defense sector especially in rocket and missile area, and it has been active in the industry for more than 25 years. The company carries out programmed project activities in addition to implementation of necessary operations to offer bid prices for possible projects. Project activities are mostly related with manufacturing, if necessary infrastructure can be obtained from either through the company's own expertise or technology transfer from an outside resource. Otherwise, the company generally designs and qualifies a customer demanded product by pursing several R&D operations. Rarely, the company can lead service operations like consultancy using existing know-how in a specific area.

The company may encounter logistics and technical risks, and the company has a better chance to manage technical risks through controllable variables in contrast to logistics risks related with other parties outside the company. Similar to logistics risks, financial management may confront with several uncontrollable variables which usually result in enormous deviations from financial expectations.

Also, the experiences of the company suggest that risk management for bidding processes of the defense industry has become inevitable due to certain occasions. The disruptions in logistics and fluctuations in exchange and inflation rates have severely affected performances of several projects in the company in last years. It turns out that the capability of the company is not the only factor determining the success for a project, since some projects with high technical success scores have not yielded the expected gain. Therefore, maximizing the profit through risk management by creating a positive shareholder value becomes the main challenge for in the bidding process of the company, while also maximizing the probability of winning to eliminate possible competitors. It is important to note that every department and every role for a project has different priorities, so many interviews are held with each party involved in order to constitute a common decision making process.

As a result, the purpose of this thesis can be summarized as coping with the above uncertainties as much as possible through robust optimization approach by maximizing both the value created for shareholders and probability of winning for an individual project. The level of value creation for shareholders is determined by using Economic Value Added (EVA) methodology, since it offers a reliable and risk-realistic measure for computing financial gain. On the other hand, robust optimization approach provides us a powerful decision tool for every scenario in which the company goes through project lifecycles. It is important to realize that consequences of risks can be easily compassed by offering higher bid prices, and this definitely leads to higher EVA. However, the probability of winning a bid decreases when then the bid price increases. In contrast, the company may suffer from financial losses while increasing probability of winning by offering lower bid prices. Hence, our main problem is to solve this trade-off by finding the optimum bid price under every risk scenario.

The rest of the study is structured as follows: In Chapter 2, the issues and the literature review related to the problem are addressed. The literature about robust optimization, pricing in the defense sector, project selection techniques, value-based performance and supply chain risk management approach, EVA methodology and utility theory are reviewed, and the bidding environment of the company is discussed in Chapter 3 to get a better understanding of the problem environment. In Chapter 4, the robust optimization model for the value based supply chain risk management is developed for the bid pricing problem of the company. Scenario determination process is explained with generated financial, technical and logistics scenarios in Chapter 5. Chapter 6 presents the computational results of our model through the comparisons with an earlier study for the company. Conclusions for the study and future research issues are discussed in Chapter 7.

CHAPTER 2

LITERATURE REVIEW

The problem under consideration of this thesis can be defined as the bid pricing problem under uncertainty so as to maximize both the added value for shareholders and probability of winning. Therefore, it is helpful to review the literature about various optimization methods under uncertain conditions, pricing techniques in defense sector, supply chain risk management methodologies with risk mitigation strategies, the value added approach with EVA methodology and utility theory for developing a better understanding about the context of this thesis.

Hence, robust optimization approach is firstly introduced in this section through comparing it with the other optimization methods in terms of their advantages and drawbacks. Moreover, we aim to present clear evidence of how useful this approach is in order to overcome problems in bid pricing process for a long-term defense project in the first section of this chapter by eliminating the possible risk factors. General project selection strategies in the literature especially for R&D projects along with pricing techniques in the defense industry are presented afterwards. In the third section of this chapter, supply chain risk management methodologies with risk mitigation strategies, value added approach and EVA methodology are clarified. Finally, utility theory is reviewed in the last section as related to our problem.

2.1. Optimization Methods under Uncertainty

Deterministic approach for problem solving is often employed in most of the mathematical models because of the simplicity it provides in the solution process, based on the assumption that the problem environment is deterministic. Actually, the problem environment and related data are often uncertain, noisy or incomplete in the real world. The problems relevant to real life such as production planning, supply chain management, scheduling, transportation, network design and finance also require a similar approach, since the decisions need to be made in uncertain environments. Lead time, returns of financial instruments, demand, and exchange and inflation rates are known as uncertain parameters for these problems, and these parameters are mostly estimated with probability distributions of occurrence. Then, the optimization models in stochastic problem environments attempt to model the uncertainty in the data by assuming that some part of the input is defined in terms of a probability distribution.

Uncertainty of parameters in the objective function prevents us from attaining the desired “optimal value”. Besides, uncertainty of parameters in the constraints can result in the violation of these constraints upon realization of the actual data. Therefore, uncertainties in these parameters have a potential influence on the usability and the reliability of the solution. As a result, the usual optimal solution can be meaningless to be used in practice with the possibility of a small uncertainty in the data. Uncertainty makes solution processes much harder especially when trying to optimize large-scale stochastic problems, therefore additional methods are needed to diminish the effects of uncertainty. Several mathematical programming approaches have been developed to be able to make decisions under uncertain conditions and the most common approaches for dealing with uncertain problem environments are the linear programming approach with sensitivity analysis, stochastic optimization and robust optimization (Sim, 2004).

2.1.1 Sensitivity Analysis in Linear Programming

Dantzig (1955) is the first to handle uncertainties for some parameters with a linear programming model, using the diet nutrition problem (Mulvey et al., 1995). Following him, Mulvey et al. (1995) state that it is logical to use the mean values to deal with the uncertainties, and thus a linear program is modeled by "best guessing" of uncertain parameters. Nevertheless, due to the fact that mathematical models are mostly an approximation of the real world, most of the decisions taken based on these assumptions can deviate from the optimal solution. Therefore, the solution quality and the reliability of the model becomes an important consideration for decision makers.

Then, sensitivity analysis is the most common technique used in previous research to measure the quality of the optimal solution. The effects of the problem parameters on the optimal solution are detected by using this analysis method (Higle and Wallace, 2003). This analysis helps dealing with the sub-optimal solutions caused by uncertain parameters by finding alternative feasible solutions for the solutions too sensitive to the uncertain parameters through sensitivity analysis.

However, sensitivity analysis can only be implemented after the model execution is finished. Therefore, sensitivity analysis is reactive when dealing with stochasticity in the suggested solution of the model developed based on the expected values of uncertain parameters, since they only try to bring out the effect of data uncertainties on the model's recommendations (Mulvey and Ruszczyński, 1995). Also, the interactions among parameters and the effects of these interactions are underestimated by single parameter sensitivity analysis. Furthermore, a feasible, near optimal solution is not always possible to obtain with sensitivity analysis and sensitivity analysis ends up being too complicated and hard to find a logical comparison, when many parameters in the model are uncertain (Balkan, 2010).

2.1.2. Stochastic Optimization

The beginning of stochastic programming dates back to the 50s and early 60s of the 20th century (Kall and Mayer, 2005). It all starts with Dantzig (1955), when the recourse model is first introduced. Then, probabilistically constrained models are introduced by Charnes and Cooper (1959) as stated by Higle (2005).

When some of the data of a linear program are most suitably characterized by random variables, a stochastic linear program comes along. Stochastic optimization is a proactive approach making use of probabilistic information in the problem data to handle the uncertainty and so it tries to optimize the expected value of the objective function (Mulvey et al. 1995). By assuming that the distributions of the input parameters are already given, the stochastic problem is optimized (Sim, 2004). In this sense, stochastic programming requires an artful mixture of deterministic mathematical programs and stochastic models (Higle, 2005).

Due to the simplicity it provides to ease the solution process during the investigation for the impact of an uncertainty, sensitivity analysis is a tempting method to study the responsiveness of the solution to uncertainties as it is stated above. However, sensitivity analysis is not appropriate for this purpose in many cases. Sensitivity analysis is applied for the purpose of defining the manner in which the solution may change with different data in the case of the existence of a concern regarding the accuracy of the problem data. When the solution or the nature of it does not change, i.e. the basis remains optimal, then the proposed solution is concluded as appropriate. However, making conclusions about the model becomes impossible when the solution is sensitive to the data (Higle, 2005).

Hence, stochastic optimization models are more reliable than sensitivity analysis because these optimization models can make a differentiation between what will be known and what will remain uncertain when the decisions are made (Higle and Wallace, 2003). It is possible to obtain results with usage of recourse models in stochastic optimization by fixing some of the decisions before information relevant to uncertainties is available, and delaying some others until afterwards (Higle, 2005). The decisions are then categorized as 'here-and-now' and 'wait-and-see' type decisions (Hahn and Kuhn, 2012). Therefore, these models provide the ability to adjust the model recommendations based on the realization of the uncertain data (Mulvey and Ruszczyński, 1995).

Considering the flexibility it provides for decision making process, setting a complete description of the probability distributions for uncertain parameters in the model may become difficult for stochastic optimization, especially when there is no historical data to make inferences about the probability distributions (Balkan, 2010). In addition, when stochastic programs grow larger in size, they become harder to solve. The cases in which the stochastic models grow larger, these optimization models are solved by making "best-guessing" or "worst-case" assumptions for the uncertain parameters recommendations (Mulvey and Ruszczyński, 1995), since it is harder to identify the complete description for the probability distributions. The best-guessing assumptions for stochastic models produce similar solutions to those obtained by using mean values in linear programs. Contrarily, the worst case assumptions result in conservative and expensive solutions (Mulvey et al., 1995).

2.1.3. Robust Optimization (RO)

Robust optimization has been introduced as a generalization of stochastic programming, concentrating on the optimality and feasibility of the solution in Mulvey et al. (1995). Nevertheless, the need for this approach has arisen before the introduction of this approach to the literature in numerous areas as in the capacity planning problem of Paraskevopoulos et al. (1991), the discussion for robustness in stochastic models of Sengupta (1991), outsourcing in the manufacturing model of Escudero et al. (1993) and multinational production scheduling problem of Gutierrez and Kouvelis (1995) (Ukkusuri et al., 2007). Robust optimization explicitly considers the risk-averse preference of the decision-maker, and so it tries to find solutions that are sufficiently insensitive to the influence of imperfect information (Scholl, 2001). RO approach can be briefly described as a scenario-based multi-objective goal programming model and it produces solutions progressively less sensitive to realizations of the model parameters from a scenario set (Mulvey et al., 1995; Balkan, 2010). Consequently, this approach creates a pro-active alternative (Bai et al., 1997).

Robust optimization and decision making under uncertainty are closely related terms. Decision-making under uncertainty is generally realized by assigning probabilities to each relevant state or utility of each outcome. Hence, this approach aims to maximize expected utility. However, the role of imperfect information is important for determining how much uncertainty is allowable. Then, the robust approach is used to reflect the level of permissible uncertainty to the system at this point (Regan et al., 2005).

In RO approach, the decision maker assigns possible point estimates to uncertain parameters and so creates scenarios along with assigning the probability of occurrence for each scenario similar to decision making under uncertainty. Scenario generation and probability assignment are not straightforward and need some effort. Nevertheless, it is possible to reduce the problem size by specifying the relationships among the uncertain parameters and ignoring the unrealistic cases (Leung et al., 2007). After the outcomes of the model are obtained, it is necessary to verify the effectiveness of the model. To accomplish this, sensitivity analysis for the scenario probabilities is used as a tool to see whether the solution depends on the assigned scenario probabilities or not. Hence, robust optimization is constructed on a thorough understanding of variability (Mason-Jones and Towill, 1998).

There are two conflicting criteria of robustness in terms of robust optimization: solutions are considered *model robust* if they are almost feasible for each scenario and *solution robust* if they are 'close' to optimal for each scenario (Mulvey et al., 1995). Also, objective robustness is another approach in RO which aims to provide a specific aspiration level for almost each scenario (Scholl, 2001).

Kouvelis et al. (1992) put forward an alternative method to robust optimization which mainly concentrates on the worst-case scenario. This approach omits scenario probabilities and does not employ scenario-specific control variables in the decision model (Scholl, 2001). By considering the lack of attention to risk-aversion, Bai et al. (1997) try to investigate the properties of risk-averse decision making approach in robust optimization.

The effect of scenario generation methods on the solution robustness is investigated in Bayraksan and Morton (2006), Kaut and Wallace (2007), and Zenios (2007). As Zenios (2007) studies statistical quality criteria to examine the effect of scenario generation methods and generated scenario sets used on the robustness of outputs. Bayraksan and Morton (2006), and Kaut and Wallace (2007) investigate decision quality to evaluate the superiority of the robust approach (Hahn and Kuhn, 2012).

Robust Optimization Model

The types of constraints in robust optimization are categorized as structural and control constraints (Leung et al., 2007).

Structural constraints (A): Constraints formulated following the concept of linear programming and input data are free of any noise

Control constraints (B and C): Auxiliary constraints influenced by noisy data

Furthermore, two sets of variables, design and control, are involved in robust optimization.

Design variables (x): Noise-free decision variables independent of the uncertain parameters

Control variables (y): Variables dependent on the uncertain parameters and the design variables

Unlike the design variables, the control variables are subject to adjustment once uncertain parameters are observed (Luo and Rong, 2009).

A framework of robust optimization is briefly described below. Firstly, let $x \in R^{n_1}$ be a vector of the design variables and $y \in R^{n_2}$ be a vector of control variables. Then, the general form of the robust optimization model is as follows (Leung et al., 2007):

$$\min \quad c^T x + d^T y \qquad (1)$$

$$\text{s.t.} \quad Ax = b \qquad (2)$$

$$Bx + Cy = e \qquad (3)$$

$$x, y \geq 0 \qquad (4)$$

Equation 2 is the structural constraint with fixed and noise-free coefficients; while Equation 3 is the control constraint whose coefficients are affected by noisy data and Equation 4 guarantees non-negativity.

Robust optimization problems require a set of scenarios $\Omega = \{1, 2, 3, \ldots, S\}$ with an associated probability for each scenario. The coefficients associated with the control constraints are $\{d_s, B_s, C_s, e_s\}$ with fixed probability p_s for each scenario $s \in \Omega$ and the sum of all associated probabilities is equal to 1.

The optimal solution of this model will be robust with respect to optimality, if it remains "close" to optimal for any realization of the scenario $s \in \Omega$, and so making the problem "solution robust". The solution is also robust with respect to feasibility, if it remains "almost" feasible for any realization of *s,* as a result making the problem "model robust" (Leung et al., 2007):

It is not always possible to reach a solution for the above model that is both feasible and optimal for all scenarios where $s \in \Omega$. Then, the multiple-criteria decision-making approach can be employed for the trade-off between the solutions, and the formulation of the robust optimization model is used to evaluate this trade-off (Leung et al., 2007).

While formulating the robust optimization model, control variable y_s for each scenario $s \in \Omega$ and error vector δ_s for scenario s that measure the infeasibility allowed in the control constraints are presented first. Hence, a robust optimization formulation related to the above mathematical programming problem is defined as following through equations 5-8 (Leung et al., 2007):

$$\min \quad \sigma(x, y_1, y_2, \ldots, y_s) + \omega(\delta, \delta_1, \delta_2, \ldots, \delta_s) \tag{5}$$

$$\text{s.t.} \quad Ax = b \tag{6}$$

$$B_s x + C_s y_s = e_s \; for \; all \; s \in \Omega \tag{7}$$

$$x \geq 0, \quad y_s \geq 0 \; for \; all \; s \in \Omega \tag{8}$$

The use of robust optimization in our study gives us the chance to manage the risk impact due to financial, technical and logistics uncertainties.

2.2. Pricing in the Defense Sector

Defense companies usually produce a large variety of products (Rogerson, 1992). Considering the company studied in this thesis, the customers of local defense market, NATO and other allies may order final products which have already successfully completed the qualification and design verification phases and are ready to be produced through serial production, whilst they may also order for new and nonexistent products based on their military needs. These products are generally manufactured in low volumes and result in high costs due to fragile supply chain operations. These products contain many supply chain uncertainties in terms of both logistics and estimation of labor hours compared with serial production. As a consequence, supply chain management risks create a considerable concern for the defense industry. Thus, the level of risk which should be eliminated is relatively higher in the defense industry than that in the comparable commercial business. Especially, the intensity of R&D projects increase the risk level in this sector. Therefore, by considering these facts, the survival of defense suppliers in the industry including the company under consideration heavily relies on the attitude of the buyers -private or government- towards compensating a certain ratio of the investment required at the very beginning of a project due to the uncertainties and high risk in the sector (Greer, Jr. and Liao, 1986).

In the defense sector, the price determination for the defense products is quite different from other sectors, since it considers factors of both competition and cost-based regulation. Defense firms can offer purely commercial products whose prices are set in a competitive manner. Nevertheless, a single source specialized in a specific area generally supplies most of the products in this sector, and so prices for these products are nominally cost-based. Then, the bid price compulsorily increases or decreases by the same amount of the projected cost of production. However, other factors also have an impact on the price determination such as the existence of a closer competitor or a cheaper alternative. The potential cost of these rivals plays an important role for cost determination. Hence, fluctuations of projected accounting cost are merely significant in more competitive bid processes where the cost of competitors has an important role. Also, the defense regulations interfere with the method that companies are allowed to utilize when calculating the cost of a product (Rogerson, 1992).

However, Rogerson (1992) suggests that government contractors have a chance to shift some of the overhead costs of their commercial operations to the government (Lichtenberg, 1992). In addition to that, current regulatory processes compose a remarkable incentive for these firms by persuading them to choose inefficient production methods for the sake of meeting the needs of the industry.

Balkan (2010) studies the bid pricing problem of the company under consideration in our study. Financial and technical risks are considered, but financial and technical decisions are not made within the model as if they are independent. Also, there is no logistics risk consideration in this study.

2.2.1. Contracting Methods for the Defense Industry

There exist several regulations about pricing for defense companies and these regulations are certainly employed in contracting processes of defense companies. United States Department of Defense (DoD) had published the Armed Services Procurement Regulations (ASPR) in 1947 to make a regulation for the defense sector and this regulation has been the most well-known and used one since then (Burns, 1972). In ASPR, DoD set up administrative boundaries on fees for any kind of negotiated contract. In 1963, Weighted Guidelines were integrated into ASPR to make a bigger percentage range of fees as an encouragement to reduce cost and improve performance and efficiency in aid of the customer.

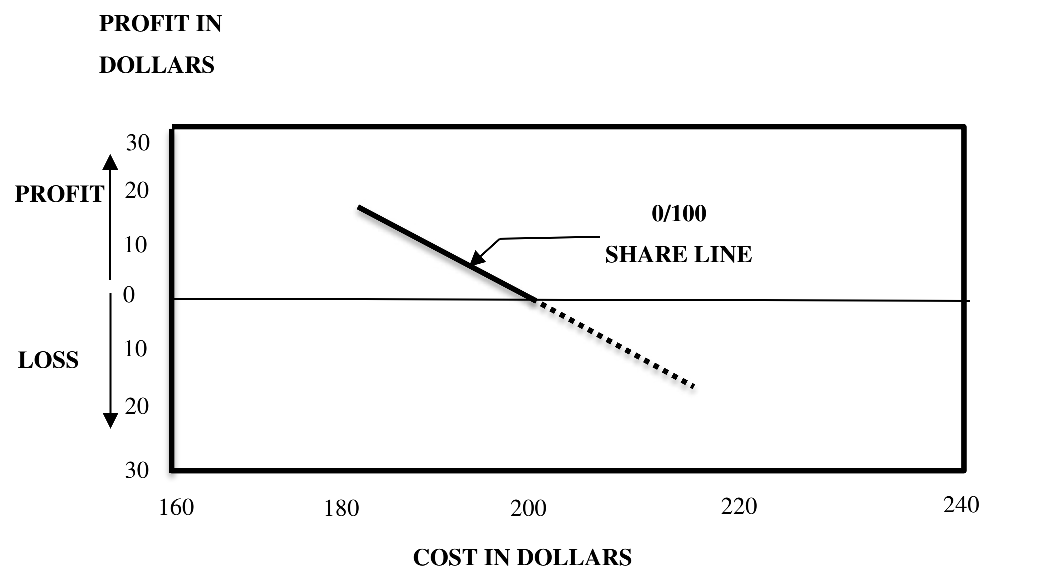
One of the alternative methods for evaluating the weights of factors in Weighted Guidelines is the weight of ‘direct material’ cost component specified based on the complexity level of the supply, i.e. managerial or technical capabilities required to supply any material defines the associated weight for a cost component. One other method is the weight of ‘engineering labor’ cost component conceived as a level of specialized engineering and scientific talent necessary to meet the requirements of the contract, and the weight of ‘manufacturing labor’ cost component conceived as the manufacturing skills and experience of employees to meet the necessities of the project are used as cost factors (Burns, 1972).

There are three main types of contracting methods implemented in the defense industry. These contracting methods are as follows (Bower and Osband, 1991):

Fixed-price-incentive (FPI): The supplier bears a constant fraction of cost underruns or overruns. The relationship of total final negotiated cost to total target cost is used to estimate contract cost and profit.

Firm-Fixed-Price Contracting (FFP): The supplier awards the bid in a competitive manner through sealed bids, and the supplier company is responsible for all cost overruns and savings.

In Figure 1, it is seen that the customer has to pay the contract price for FFP type contracts, independent from the actual cost (Engelbeck, 2002).



Contract Price	$200	$200	$200
Final Cost	$185	$170	$220
Profit	$15	$30	-$20

Figure 1 FFP Pricing Arrangement

Cost-Plus-Fixed-Fee Contracting (CPFF): The supplier is reimbursed its actual cost in addition to the target fee. More economic production is encouraged by this contracting method.

This contracting type is often used contracting method nowadays in military and government companies to put the risk on the side of suppliers, and provide efficiency in costs for customers (Allan, 2004).

2.2.2. Overhead Allocation Concept for the Defense Industry

In the past, direct costs such as material and labor costs constituted the majority of total costs for companies, as a result cost management was relatively easy. This fact is not valid for today's business environment. The size of the business, the nature of the product range and features of the market it serves increasingly affect the significance of overhead costs. Thus, the ratio of overhead cost to direct cost has grown over time.

Companies requiring advanced technology and complex production processes with complicated supply chain distribution operations have a tendency towards high levels of overhead in all their operations. High technology asks for a high capital investment, which inevitably creates a complex environment as associated with high rate of overhead costs (Falcão, 1993).

The data from American defense industry indicates that a significant portion of DoD dollars spent in the procurement of defense systems is constituted by overhead costs, representing 30 to 50 percent of total cost for most aerospace contractors that are very similar to defense suppliers (Boger, 1983). Falcão (1993) hence states that overhead cost control has become an area of special concern to Government Contract Management in DoD, and so there are many regulations handling with these cost types.

Therefore, overhead allocation constitutes a significant concept for the defense industry in general, mainly due to the fact that long term project engagements require constant resource allocation for vendors, and manufacturing processes require high technology.

Moreover, uncertainties about the future bring out several risk considerations and related costs for the defense companies. As a result, companies in this sector aim to guarantee to cover a certain amount of the overhead costs in the project's lifecycle when contracting a long-term project (Rogerson, 1992). Then, the overhead allocation concept for the defense sector is shortly stated by Fox (1974) as follows: "Profit is not a defense contractor's only concern when bidding on or conducting a development or production program. Defense contracts are sought to cover payroll and overhead costs, and to provide company personnel with the opportunity to develop technical and managerial skills useful in future commercial and defense businesses."

2.3. Project Selection Methodologies

Project selection is an important activity in many organizations, because it directly affects the following project management activities as stated by Archer and Ghasemzadeh (1999), Cooper (1993), Martino (1995), and Meredith and Mantel, Jr. (1995). In addition, there are usually more projects available for selection than can be undertaken within the physical and financial domain of a company, so decisions must be made based on suitable project selection criteria (Archer and Ghasemzadeh, 1999).

Methods and techniques for selecting projects have appeared in the literature for at least 40 years. Approaches related to selection process tend to be either quantitative or qualitative, ranging from rigorous operations research methods to social-science-based interactive techniques (Henriksen and Traynor, 1999). Among these techniques, many of them are not commonly used, because they are too complex to implement and ask for too much input which may be very difficult to obtain. They may become too difficult to put into practice, or they may not be suitable to use for an organized process (Cooper, 1993). Despite these facts, it has been suggested (Roussel et al., 1991) that the role of project portfolio selection will grow and become much more important owing to growing competitive pressures in the global economy. Companies that aim to be competitive by selecting the most appropriate projects then must use techniques based on the most critical project measures for project selection (Archer and Ghasemzadeh, 1999).

Profitability models, scoring models and multi-attribute utility models are the most frequently used methods in project selection. These models approach the project selection problem as a constrained model aiming to optimize the resource allocation among different projects whilst maximizing the gain (Burton and Nishry, 1965).

There exist some common elements to be considered in project evaluation and selection models specified by Balkan (2010) as,

- probability of success (Papoulis and Pillai, 2002; Chien, 2002; Åstebro, 2004; Eilat et al., 2008),
- resource allocation (Liberatore, 1987; Liberatore, 1988; Iyigun 1993, Kocaoglu and Iyigun, 1994; Morcos, 2008),
- payback period or gain of the project (Liberatore and Titus, 1983; Akhilesh, 2014),
- market share impact and government funding as the non-monetary benefits (Wallsten, 2000; Huang et al., 2008).

Also, selection methods can usually be placed into one of the following categories for the selection of projects (Henriksen and Traynor, 1999):

- unstructured peer review,
- scoring,
- mathematical programming,
- economic models,
- decision analysis,
- interactive methods,
- artificial intelligence,
- portfolio optimization.

2.3.1. Scoring Models

Scoring as a technique for evaluation has appeared in various forms. It is appropriate to employ when there is a low degree of interdependence among decision factors, that is, when the activities and results of one factor do not depend on the activities and results of a different factor (Henriksen and Traynor, 1999).

The scoring model is a linear model in which project scores constitute the main ground for project evaluation. It is not possible to measure the magnitude of desirability for a project due to ordinal scale project ranking. Moreover, since the profitability or risk is not computed in usual business terms, making a comparison among projects becomes impossible. Scoring model overcomes this drawback through a checklist containing all related elements with important intangible elements (Balkan, 2010).

Furthermore, scoring models require a relatively less number of decision criteria, such as cost, work force availability, probability of technical success, etc. to determine the ranking of a project. The merit of each project is determined with respect to each criterion. The algorithm is shaped in a way that the weight distribution of each criterion emphasizes the importance of that criterion among others. Then, the results are combined to get an overall benefit measure for each project using the algorithm. A major advantage in this model is that projects can be added or deleted without re-calculating the merit of other projects (Martino, 1995). Moreover, scoring does not require detailed economic data some of which may not be readily available. In addition, scoring tools can be customized by an organization to articulate the characteristics she wants to emphasize (Henriksen and Traynor, 1999). The flow diagram employed for scoring modeling process is stated by Burton and Nishry (1965) as in Figure 2.

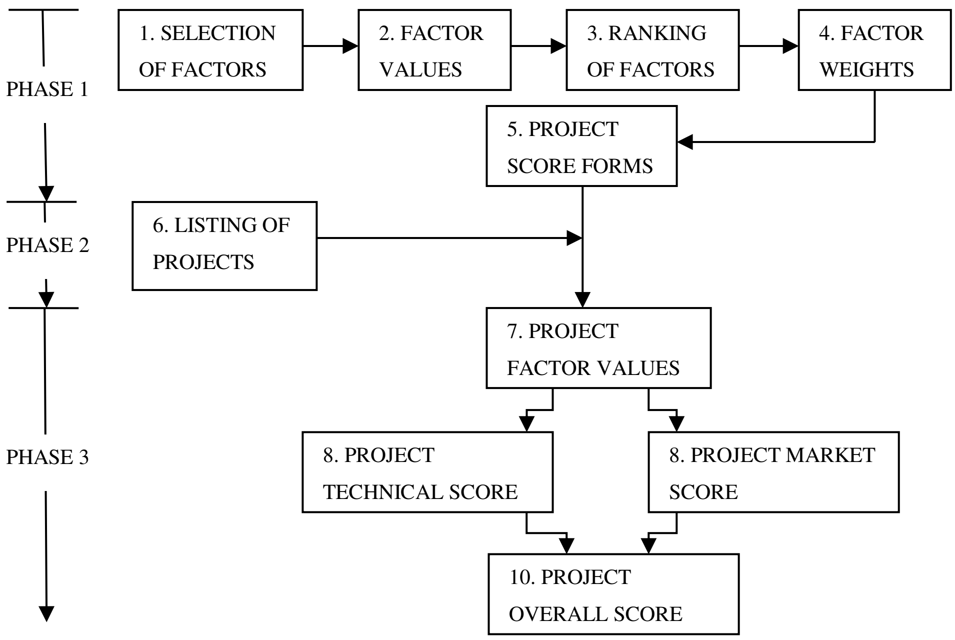


Figure 2 Flow Diagram for the Scoring Models

2.3.2. Profitability Models

Profitability models require specific economic, sales, and technical information that are usually available with historical data. These models allow for including nonlinear elements by using interactions among variables. A well-defined performance measure with a cardinal scale described by the present value of future profits is utilized to evaluate the profitability of each project and therefore it becomes possible to make a comparison among projects regarding profitability. Additionally, the profitability models may be used to evaluate the risks and utilities associated with the performance of projects (Burton and Nishry, 1965). However, there are some drawbacks of this model, such as need for extensive data, measurable input variables, and point estimates for the values of variables.

The comparison among scoring and profitability models is given in Table 1 by considering their main characteristic features (Burton and Nishry, 1965).

Table 1 Comparison of Scoring and Profitability Models

Model \ Comparison	ADVANTAGES	DISADVANTAGES
SCORING	• Simplicity • Minimum data requirement • Intangible factors	• Non-utility scale • Linearity assumptions
PROFITABILITY	• Utility scale • Nonlinear factors	• Hard to use • Minimum data requirement • Tangible factors

2.3.3. Multi-Attribute Utility Models

The utility concept in complex decision problems including multiple attributes and multiple conflicting objectives is employed by Keeney and Raiffa (1993) with a systematic approach of multiple attribute utility analysis. Multi-attribute utility models are implemented for solving problems of trading off the achievement of some objectives against others by maximizing overall utility. When a decision maker is presumed to be facing this problem and has to pick up one from a group of alternative decisions, multi-attribute utility models are deployed to state the decision maker's preference structure by modeling it mathematically with a multiple attributes utility function (Sanayei et al., 2008). This function provides the decision maker with an optimal solution. Hence, multi-attribute utility theory makes it possible for the decision maker to turn a complex problem into the form of a simple hierarchy and to subjectively comment on a large number of factors in the presence of uncertainty (Stewart and Mohamed, 2002).

Throughout the solution process of multiple-attribute utility models, each performance measure is turned into a scalar performance measure, and the performance conversion function contains the risk preference of decision makers (Balkan, 2010).

The major advantage of multi-attribute utility theory is that this theory enables one to tackle with both deterministic and stochastic decision environments at the same time (Zionts, 1992). Thence, systematic nature of multi-attribute utility theory in dealing with complex problems with conflicting criteria makes it especially very suitable for selecting a firm’s project portfolio and associated bid alternatives with the projects in the portfolio (Sanayei et al., 2008).

2.4. Utility Theory

Utility is a scale of desirability or satisfaction over a need or want, and assures a uniform measure to compare and/or consolidate quantitative and qualitative factors (Stewart and Mohamed, 2002). Utility theory is then relevant to people's preferences and this theory plays an important role in decision making processes. There exist two categories to interpretations of utility theory: prediction and description. In the predictive approach, a theory is studied to predict the actual choice behaviors, and social sciences are mainly interested in predictive approach. However, management science, statistics and economists are primarily interested in descriptive approach which formulates how a decision ought to be made by decision makers (Fishburn, 1968).

The conceptual and practical difficulties of the concept of utility, and particularly of the attempts to quantify it, are obvious. Hence, defining utility is not a simple process that is totally dependent on the decision maker's preference. A utility function reflects the preferences of a decision maker as a number by assigning a numerical index to varying levels of satisfaction of a criterion (Mustafa and Ryan, 1990). A common and effortless way to do this is to implement a utility function which will gradate the utility between 0 and 1, specifying 0 as the least favorite and 1 as the most favorite (Naert and Weverbergh, 1978).

2.4.1. Expected Utility

All required data are not available in most decision making processes, which means that decision maker has to be content with imperfect information already on hand. Consequently, most decisions are made by facing uncertainty. In uncertain environments, utility will also be definitely uncertain. For this reason, probability takes an important part in the decision making process by playing the role of a substitute for certainty and trying to complete the knowledge already available (Golub, 1997).

By utilizing probability functions, the notion of the expected utility helps decision makers to make better decisions. The expected utility is expressed as the weighted average of the utilities for each possible outcome, where the utility of an outcome measures the preference level of that outcome with respect to the alternatives. The utility of each outcome is weighted regarding the probability that the act will result in that specific outcome (Briggs, 2014). Then, the expected utility of an act, A, for two outcomes (O_1 and O_2) with expected utility function $u(A)$ where p is the probability of occurrence of that outcome is basically expressed by Friedman and Savage (1948) as:

$$u(A) = p_1 u(O_1) + p_2 u(O_2),$$

where $p_1+p_2=1$.

2.4.2. Multi-Attribute Utility Theory (MAUT)

According to von Winterfeldt and Fischer (1975), MAUT joins a class of psychological measurement models and scaling procedures which can be implemented for the evaluation of alternatives with multiple value relevant attributes. MAUT may be advantageous as a decision aiding technology for dissociating a complex evaluation task into a set of simpler subtasks.

MAUT basically relies on the expected utility theory (von Winterfeldt and Edwards, 1986; French, 1988) and demands for more powerful assumptions to ensure additivity. The benefit of this theory is that it can take stochasticity into consideration and place it directly into a decision support model. Hence, MAUT is also called as strong form of decision making (van Herwijnen, 2012).

In MAUT, utility of multiple-attribute outcomes is defined as a function of the weighted attributes (Torrance et al., 1982). Different function forms are available in MAUT models as additive, multiplicative, and multi-linear.

Butler et al. (2001) represents the general form of a multi-attribute utility function shown below, where X_i is the realization of attribute i; $u_i(X_i)$ is a single attribute utility function for attribute i; w_i is the related weight with attribute i and w_{ijm} are the scaling constants indicating the effect of the interaction among measures i, j and m on preferences.

$$u(X) = \sum_{i=1}^{n} w_i u_i(X_i) + \sum_{i=1}^{n} \sum_{j>i} w_{ij} u_i(X_i)\, u_j(X_j) + \sum_{i=1}^{n} \sum_{j>i} \sum_{m>j>i} w_{ijm} u_i(X_i) u_j(X_j)\, u_m(X_m) + \cdots + w_{123\ldots n} u_1(X_1) u_2(X_2) \ldots u_n(X_n)$$

Additive form

To be able to use the additive form of multi-attribute utility function, additive independence condition of attributes must hold. Additive independence condition is satisfied, if only preference of an attribute is independent from other attributes (Butler et al., 2001). This form of multi-attribute utility functions provides computational simplicity, and the additive form to find total weighted utility is frequently used as:

$$\sum_i w_i \, u_i(A_i)$$

$$\sum_i w_i = 1,$$

where $u_i(A_i)$ is a single attribute utility function and $w_i$is the relative weight.

Multiplicative form

The existence of mutual independence among attributes gives decision maker the chance of using multiplicative form of MAUT function. Butler et al. (2001) defines the main form of a multiplicative function in below where *w* is the impact of interactions for all attributes, $u(X)$ is a multiple attribute utility function, $u_i(X_i)$ is a single attribute utility function and w_i is relative weight as:

$$\begin{aligned} u(X) = \sum_{i=1}^{n} w_i u_i(X_i) + \sum_{i=1}^{n} \sum_{j>i} w w_i w_j u_i(X_i)\, u_j(X_j) \\ + \sum_{i=1}^{n} \sum_{j>i} \sum_{m>j>i} w^2 w_i w_j w_m u_i(X_i) u_j(X_j)\, u_m(X_m) + \cdots \\ + w^{n-1} \prod_{i=1}^{n} w_i u_i(X_1) \end{aligned}$$

2.5. Supply Chain Risk Management (SCRM)

The production and supply chain operations environment has dramatically changed in recent years. Supply chains have become more vulnerable in today’s competitive environment due to globalization effect, short product life cycles and pressures for lean production. Apart from that, disruptions in supply chain can occur as a result of natural disasters, accidents, and the volatility of the financial market. Companies have experienced that a minor disruption in the supply chain might immediately influence the operational abilities of the company. Hence, supply chain management nowadays has a new challenge of maintaining the expected yields of the supply chain being exposed to risks, and so the importance of decision-oriented approaches to supply chain risk management is increasing (Jüttner et al., 2003).

Even though there is much discussion on risk management related topics in the literature, they only consider the single organizational structure. Experience gained from a single company perspective cannot be applied to a supply chain context sufficiently, since it does not represent a supply chain orientation which has multiple actors (Jüttner et al., 2003). According to Mentzer (2004), simplest degree of complexity in supply chain comprises three elements: a company, a supplier and a customer directly involved in the upstream and downstream flows in the supply chain. Supply chain management then must assure a coordination among these interdependent organizations and so can be defined as “the management of upstream and downstream relationships with suppliers and customers in order to create an enhanced value in the final market place at less cost to the supply chain as a whole” (Christopher, 2005).

To demonstrate the differences between a single company’s point of view and supply chain perspective, risk analysis process can be given as an example. Evaluation of possible risks and their effect on company operations is a complex and difficult task for a single organization. For identification of vulnerabilities in a supply chain context, companies must identify the risks to all entities as well as those risks caused by the linkages among the organizations (Christopher, 2005; Jüttner et al., 2003).

To get in more detail about SCRM, a clarification for the nature of risks in terms of the supply chain is needed. Despite the fact that risk is a subjective term and there is not any generally accepted definition for it (Baird and Thomas, 1990), risk is most commonly defined as “variation in the distribution of possible outcomes, their likelihood’s, and their subjective values” (March and Shapira, 1987). Risk in the supply chain, however, concentrates on the disruption of “flows” among organizations (Jüttner, 2005).

SCRM in corporational terms is defined by Jüttner (2005) as “the diagnosis and management of supply chain risks with participation of all parties for the sake of holistically minimizing supply chain vulnerability”.

To handle the difficulties in SCRM, identification of potential risks, evaluation of their impacts and design of flexible plans before their occurrences are needed to be managed carefully. In addition, risk mitigation strategies should be developed to be employed after the occurrence of risk events by recomposing resource allocation to mitigate from risks as much as possible.

The basic constructs of supply chain risk management are as follows in Figure 3 (Jüttner et al., 2003):

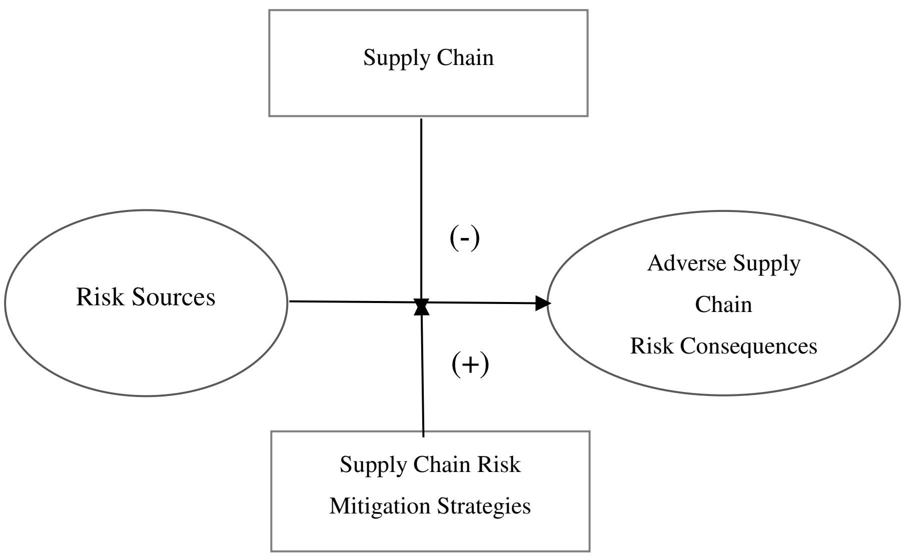


Figure 3 Basic Constructs of Supply Chain Risk Management

2.5.1. Supply Chain Risk Sources

Supply chain risk sources are any unpredictable factor from which disruptions can arise. Mason-Jones and Towill (1998) propose five overlapping groups of supply chain risk sources: environmental, demand and supply related, operational and control risk sources.

Environmental risk sources cover external uncertainties caused by the supply chain such as disruptions as a consequence of political, natural or social uncertainties. Demand and supply related sources are, however, internal to the supply chain. Supply risk is the uncertainty related with supplier associated activities, whereas demand risk is any risk related to the outbound logistics flows (Svensson, 2002) and product demand (Johnson et al., 2001). Environmental risks can result in supply or demand risk, that is, i.e., these risk sources overlap with each other. The risk exposure of a supply chains defines its vulnerability at the same time.

Supply chain risks include any disruption risk in the flows information, material and product. The sources for this risk can be organizational or supply chain-related in addition to environmental factors including uncertainty. These factors can affect the supply chain related variables as costs and/or quality (Norrman and Jansson, 2004).

2.5.2. Supply Chain Risk Mitigation Strategies

A clear differentiation of supply chain risk drivers and mitigating strategies is needed in the context of supply chain risk management. Because competitive pressures are often classified as risk drivers, "calculated risks" term is employed in a way that a company takes so as to be more competitive by reducing costs, and improving profitability (Svensson, 2002). However, as it is stated by Miller (1992), risk mitigating strategies are strategic moves intentionally born by companies so as to mitigate from different uncertainties as a consequence of several risk sources (Jüttner et al., 2003).

Numerous strategies can be employed by firms to manage the disruption risks. Firms can employ mitigation strategies before a disruption occurrence, and hence the cost of these actions is paid independently from the occurrence of the disruption. Contingency plans on the other hand are the actions that firms take if only a disruption occurs. The application of these strategies result in investment costs, and firms can choose passive acceptance for some disruption risk instead. In fact, passive tactic is the most deployed strategy for most firms (Tomlin, 2006).

A group of strategies for risk mitigation used by companies is specified in Table 2 as:

Table 2 Risk Mitigation Strategies in Supply Chains (Jüttner et al., 2003)

Avoidance	- Dropping specific products/geographical markets/supplier and/or customer organizations
Control	- Vertical integration - Increased stockpiling and the use of buffer inventory - Maintaining excess capacity in productions, storage, handling and/or transport - Imposing contractual obligations on suppliers
Cooperation	- Joint efforts to improve supply chain visibility and understanding - Joint efforts to share risk-related information - Joint efforts to prepare supply chain continuity plans
Flexibility	- Postponement - Multiple sourcing - Localized sourcing

Firms are free to employ any strategy or a combination of available strategies in accordance with their strategic priorities to manage disruption risks. Managers should consider two steps while choosing organizational supply chain risk management strategy, since there are several types of risks and risk-mitigation strategies related to these risk types. First of all, a common understanding of supply chain risk should be developed in an organizational frame. Secondly, managers should choose the most appropriate risk-mitigation tactics for their own company and when to employ these strategies in their particular circumstances.

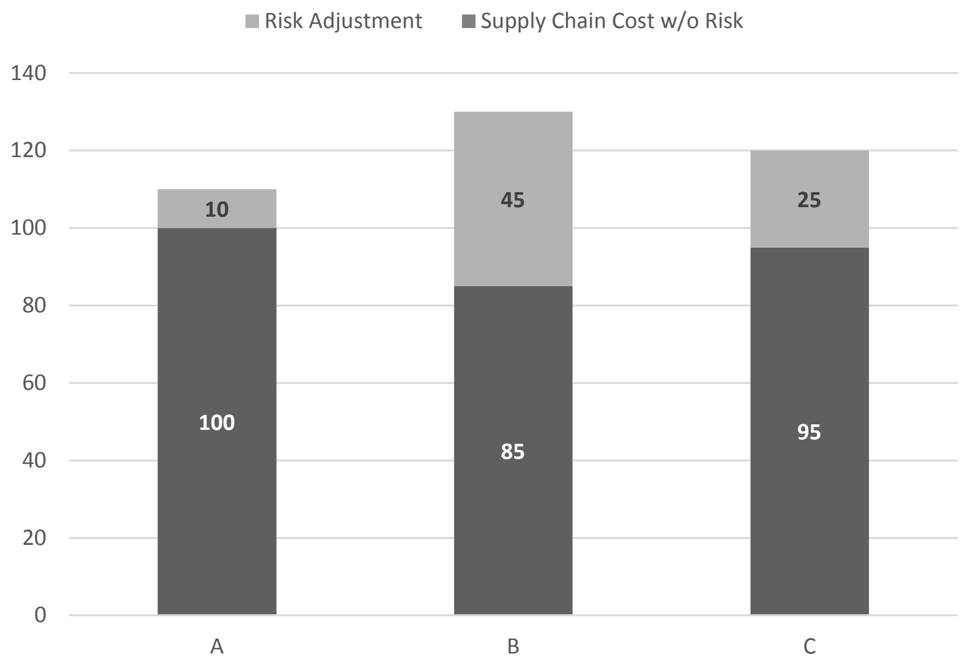
Risk mitigation with reserves such as inventory, capacity, redundant suppliers and responsiveness is a common method used by companies. However, management should not underestimate trade-off between the risk and the cost as a result of mitigation from it (Chopra and ManMohan, 2004; Chopra and Miendl, 2004). To achieve an optimal balance for this trade-off, three key relationships should be considered.

The first one is the increasing cost of risk reduction. This relation offers that the inventory holding costs are higher to compensate for a high level of demand risk than covering a low level of risk as expected. The second one indicates that risk pooling decreases the reserve amount required for a specified level of risk coverage. The third relationship states that the benefit of risk pooling increases with the level of risk covered (Chopra and ManMohan, 2004).

Supplier selection is another critical factor for supply chain risk mitigation. Efficient suppliers with lower costs should be chosen for low risky items, whereas more responsive suppliers are required for high risky and high valued items (Tomlin, 2006; Christopher and Lee, 2004).

Yet, robust supply chain strategies enable a firm to employ the associated contingency plans in an efficient and effective way when dealing with disruptions. As a result, a company becomes more resilient to risks by pursing a robust supply chain strategy.

For effective management of supply chain risks, firms should not treat risk optimization problem as a tool to reach a single goal of reducing cost or risk. In reality, cost or risk minimization cannot be accomplished with this way. Operating costs and supply chain risks must be in balance to optimize the trade-off between highest profit strategies and responsiveness. This balance requires a harmonic mixture of a static and a catastrophic strategy as shown in Figure 4 (Kilgore, 2004).



Alternative Risk Mitigation Strategies

Risk Adjustment = Event Probability x Cost Impact

Figure 4 Analytical Risk Mitigation Determination of the Optimal Risk Mitigation Strategy (Kilgore, 2004)

Applying Analytical Risk Mitigation Steps

Analytical risk mitigation approach enables firms to diversify their risk with a lower cost increase and the lowest long-term cost. Companies can predict possible failures before they occur with risk analysis strategy. Following analytical risk mitigation framework can be used by companies to employ a risk oriented supply chain strategy (Kilgore, 2004):

1. ***Identification of centralized risk factors:*** Companies should first determine where the bottlenecks are in a single element such as location, organization, or flow. This process requires a holistic approach including all supply chain nodes. After determination of all supply chain nodes with their related risks,

the interactions between these nodes should be examined for additional risk factors.

2. ***Highlighting high-contingency risks:*** After identification of risk elements, it is possible to classify risks according to their contingency levels. Then, requirements for risk prevention can be specified with related cost.

3. ***Assignment of risk probabilities:*** Once the determination of risks and their relative importance have been completed, the probability of their occurrences over a given period should be identified either by using quantitative data or intuition- if no such data exist.

4. ***Assessment of the impact associated with each risk:*** After setting the risk probabilities, it is time to define the associated risk impacts. Not only cost and profit but also shareholder value is directly affected by poor performance resulting from risk impacts. A study about the cost of supply chain failure implies that disruptions in supply chain reduce shareholder value by around 20% (Singhal, 2000).

5. ***Evaluation of the cost of risk mitigation:*** Performance is enhanced through risk reduction. However, risk mitigation should not be preferred for every risk keeping in mind the fact that the cost of avoiding from a risk can be greater than its impact.

2.6. Value-Based Risk Management and EVA Approach

Shareholder value creation, which is mostly regarded as top level business aim of companies (Young and O'Byrne, 2000) demands for the integration of performance and risk management (Ritchie and Brindley, 2007; Oehmen et al., 2007). Creating value for the customers and shareholders through supply chain management by regulating business operations is quite a popular topic in the literature and the question of how this can be succeeded is the main challenge.

Value driver trees and risk-adjusted performance metrics are employed in value-based management as major concepts for performance and risk management (Kaplan and Atkinson, 1998). According to Rappaport (1998), value driver trees divide top-level performance metrics into operational branches for performance management. Risk indications are reckoned within the performance metrics over risk-adjusted cost of capital (Young and O'Byrne, 2000).

Deterministic decision frameworks for value-based performance (Walters and Lancaster, 1999; Lambert and Pohlen, 2001) and risk management (Cavinato, 2004; Oehmen et al., 2007) are examined in terms of supply chain context. Hahn and Kuhn (2012) develop a perspective for integrated value-based performance and risk optimization at mid-term level with robust optimization approach to consider the risk-averse attitude of management and neutralize the effect of imperfect information for financial performance.

This approach is realized with applications such as;

- Definition and implementation of strategies whose first priority is to obtain the highest potential for shareholder value,
- Establishment of information systems centered on all variables related to value creation,
- Reorganization of management operation from value creation perspective,
- Formation of necessary tools to measure the effects of value creation (KPMG Consulting, 1999; Pricewaterhouse Coopers, 1999).

Value added perspective requires for dealing with finance, operations management and logistics, and provides decision makers with the chance to view possible operations to create value for the company (Ittner and Larcker, 2001).

Several techniques for shareholder value management have been employed during the past decade. One of these methods stated by Wood (2000) is EVA approach. EVA method is known as one of the best financial performance tools to capture the true economic profit of an enterprise. This term is firstly used by Stern Stewart &

Co., and it gives weight to value creation by the management for the shareholders (Shil, 2009). It is stated by Shil (2009) that “Profit maximization as a concept is age-old, wealth maximization is matured and value maximization is today’s wisdom” to emphasize the current position of EVA for business perspective. EVA demands a certain level of accounting information, but this level is more than the data requirements of the traditional methods. Therefore, EVA should be shaped according to accounting system, corporate strategy and the desirability for such a system by management.

A positive EVA suggests shareholder wealth has been increased, whereas a negative EVA means that several prompt actions are required to prevent from results of bad investment decisions. The existence of negative level for EVA also implies that the company should not progress to buy any potential asset leading less return than the weighted average cost of capital (Walters, 1999).

Nowadays, the main motivation for management is to find ways for increasing shareholder value creation. Also, even though they realize that the accounting profit terms do not ever accurately represent the real shareholder value created, they may be used in the calculation process by being converted to economic profit. EVA is explained by Stewart (1990) as Net Operating Profit after Taxes (NOPAT) from which a cost of capital is subtracted.

2.6.1. EVA vs. Other Financial Instruments

The return on capital is a frequently used and functional financial performance measure among other traditional methods. Different methods such as return on investment, return on assets and internal rate of return can be employed to find the return on capital. The most significant drawback of all these rates for the return on capital is that maximizing rate of return is not necessarily mean maximizing value for shareholders. For instance, internal rate of return is a useful method to evaluate a project and investment alternatives, yet it is not suggested to make a choice among options only based on their relative internal rates of return (Shil, 2009).

Other than EVA, there are a range of other value-based measures such as adjusted economic value added, cash value added, refined economic value added and cash flow return on investment. These various value-based approaches in fact can capture the same goal for an organization as EVA, even though their names differ (Shil, 2009).

2.6.2. EVA Computation Steps

Certain main steps are demanded for the computation of EVA. Common steps which can be changed according to characteristics of business or processes are in the following (Shil, 2009):

1. ***Financial data collection:*** Financial data which is a product of traditional accounting methodology is needed for EVA. Hence, a critical portion of the data used for EVA is obtained from traditional financial statements.

2. ***Distortion elimination:*** Financial statements are subject to distortions and these distortions should be identified before finding the true EVA value. After identification of distortions, necessary actions should be taken for normalization of financial statements.

3. ***Capital structure determination:*** All invested money in the company independent from its origin, ownership or borrowing, constitutes the capital structure for that company. The capital structure is defined as total assets minus non-interest bearing liabilities in the beginning of the period by Stewart (1990).

4. ***The weighted average cost of capital (WACC) identification:*** The cost of capital is defined as the minimum acceptable level for rate of return which the company is willing to accept for any investment (Park, 2007). Cost of capital calculation is a challenging activity for companies. Fund using, not source utilization, defines the cost of capital as it is stated by Ross et al. (2005). Also, there are several other factors affecting the cost of capital such as business risks, shareholder expectations, macro-economic variables.

Various financial management tools can be employed to find the cost of capital. Among them, WACC offers a quite commonly used and easy way to make calculations. While finding WACC, some financial measures are required such as parts of capital employed and their respective weights, elements affecting the risk and return for parts of capital, and most importantly individual cost of each part (Copeland et. al., 1996).

Then, WACC can be calculated in the following equation as:

$$WACC = (R_{ce} \text{ x } W_{ce}) + (R_{pe} \text{ x } W_{pe}) + (R_d \text{ x } W_d)(1 - T_c) + (R_x \text{ x } W_x)$$

where individual costs of all parts R_{ce}, R_{pe}, R_d and R_x represent common equity, preferred equity, debt and other costs respectively, *W*'s are their relative weights and T_c is the tax rate for the company.

5. ***NOPAT Determination:*** NOPAT helps us to calculate the cash generation capability of a company from regular business activities (Dierks and Patel, 1997). It is derived from NOP minus calculated taxes from NOP as described:

$$NOPAT = NOP \text{ x } (1 - T_c)$$

6. ***EVA calculation:*** As the final point, EVA can be calculated by NOPAT minus capital charges with the following equation (Stewart, 1991; Reimann, 1988):

$$EVA = NOPAT - Capital\ Employed \text{ x } WACC$$

In summary, it is seen by the above background that robust optimization methods are appropriate to employ in physical supply chain planning in addition to financial performance and risk management. However, we realize that current approaches do not provide a robust approach framework for value-based performance and risk optimization in terms of bid pricing. Hence, our aim is to examine the bid pricing problem by implementing value-based supply chain risk management concept through robust optimization (Hahn and Kuhn, 2012).

CHAPTER 3

PROBLEM DESCRIPTION

The company under consideration carries out several business development and marketing operations, and while pursuing these operations it also considers customer dominant requisitions to create value for shareholders. Hence, potential projects with different characteristics can emerge for the company.

Even though each project of the company differs from the others more or less, it is possible to define them according to certain criteria. In terms of project characteristics carried out by the company, project lifecycles usually change from 2 to 10 years, and hence can be classified from medium to long term duration, similar to any other company in the defense and aerospace industry. Kerzner (2013) states that projects in defense and aerospace industries have faced with cost overruns of more than 200 to 300 % due to inability to forecast technology in the past. The main reason for these cost overruns is that forecasting is rather difficult for long term projects, and this fact is also valid for the company under consideration. Also, the projects of the company can be classified according to the level of production and design activities.

Candidate projects of the company go through certain evaluation processes. First of all, after a possible project is briefly examined in technical and financial terms with respect to the strategic plan and the operational capability of the company, a much more detailed analysis is conducted. If detailed analysis results show that the requirements of the candidate project and the priorities of the company match, then the bid pricing process for the project is started. Otherwise, the company does not spend any further effort for the candidate project. Since feasibility is a crucial topic for project evaluation, these operations provide important findings for pre-evaluation of candidate projects.

The process before the bid preparation phase for national defense sector is as in the Figure 5 (Balkan, 2010) where SSM/MSB defines The Ministry of Defense and TÜBİTAK defines The Scientific and Technological Research Council of Turkey:

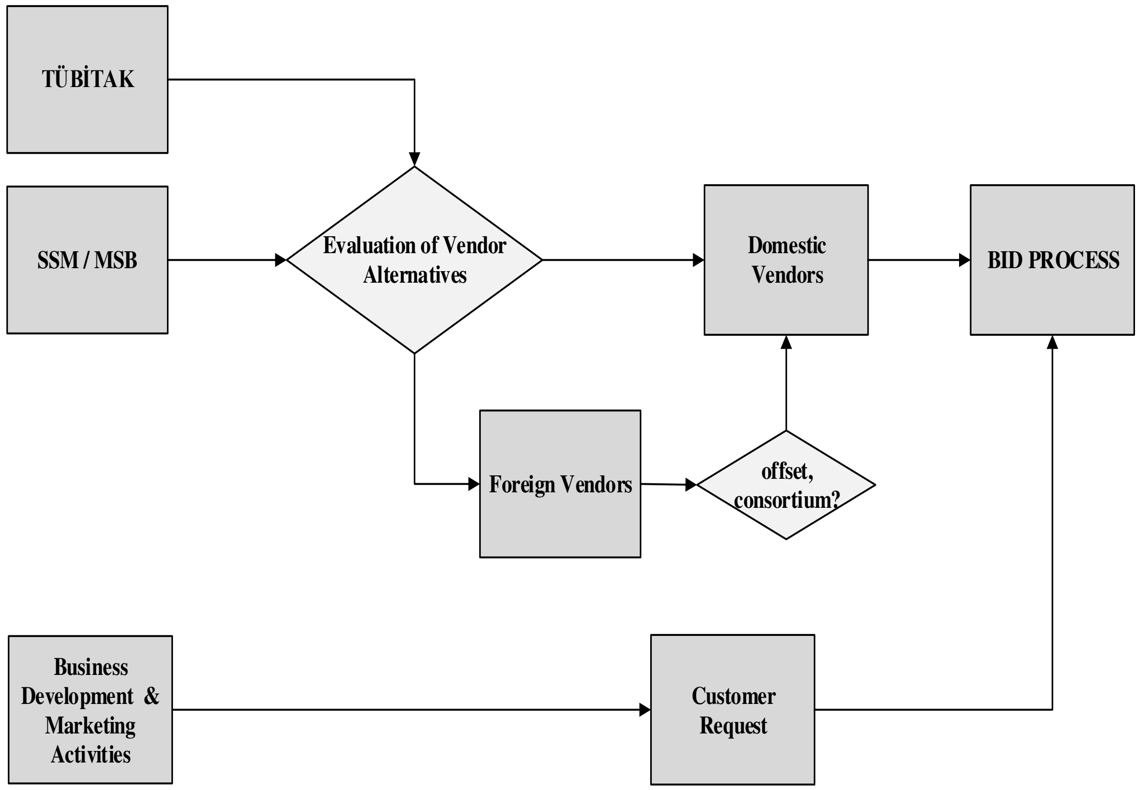


Figure 5 Pre-Bid Process for the Defense Industry

3.1. Project Characteristics

Projects are defined as organizational efforts for achieving business goals to satisfy customers' requests and needs. Therefore, the management of projects is more complicated than the management of routine operations. Project activities such as signing contracts, selection of effective project teams, arrangement of the business strategy and administration of diverse teams for better performance are usually pursued only once in several years compared to lifecycle of projects. Also, these activities that significantly affect the success of business are conducted separately for every new project (Sadeh et al., 2010).

Hence, a much more meticulous project management approach is mandatory due to high value of the projects for project-driven industries such as aerospace, defense and large construction as it is stated by Kerzner (2013) in Table 3. Requirement levels for project management principles for different project types can be seen in Table 3 including defense projects.

Table 3 Classification of Projects/Characteristics (Kerzner, 2013)

	Type of Project/Industry					
	In-house R&D	**Small Construction**	**Large Construction**	**Aerospace/ Defense**	**MIS**	**Engineering**
Need for interpersonal skills	Low	Low	High	**High**	High	Low
Importance of organizational structure	Low	Low	Low	**Low**	High	Low
Time management difficulties	Low	Low	High	**High**	High	Low
Number of meetings	Excessive	Low	Excessive	**Excessive**	High	Medium
Project manager's supervisor	Middle management	Top management	Top manageme nt	**Top management**	Middle management	Middle management
Project sponsor present	Yes	No	Yes	**Yes**	No	No
Conflict intensity	Low	Low	High	**High**	High	Low
Cost control level	Low	Low	High	**High**	Low	Low
Level of planning/ scheduling	Milestones only	Milestones only	Detailed plan	**Detailed plan**	Milestones only	Milestones only

In an attempt to make our problem environment more clear, each bid won by the company generates a project and its related activities, but before that, pre-bid processes have been already executed. Therefore, it is required to review the project perspective of the company in the scope of this study. To begin with, we define the characteristic project features in the company to become more aware of the problem environment.

Project type: It is possible to distinguish the projects conducted by the company regarding to their different characteristics. Although there are lots of different classification methods for project type distinction, our examination in terms of this specific company results in the below project types carried by the company:

- ***Research and development (R&D) project*:** These projects require intensive engineering and specialized labor, and they are very essential for getting ahead of the rivals in competitive business environment due to experience gained for prospective developments. Since R&D projects have several uncertainties by their very nature, the company mostly needs a financial support from the government to root for such projects. Hence, it is possible to employ government funding mostly for specific cost types as labor and material costs in a specified percentage for this project type. Most of the activities in R&D projects are non-recurrent.

- ***Production type project*:** These projects require profound knowledge and capability for the product produced in the project, therefore design and design qualification stages are mostly skipped in production projects, and it is presumed that the final product totally complies with client's expectations. However, if a project requires for minor modifications in Bill of Materials (BOM) or any alteration in the production method or process of a current production project, this new project is also accepted as a production type project. Briefly, these projects include the products either already a member of the existing product portfolio or convertible from a current product in the portfolio with small modifications in BOM and/or production operations.

- ***Service type project:*** The company does not only conduct production or design operations. Thanks to the experience gained in the defense industry, the company can perform test supports, construction of turn-key factories, and laboratory for requesting clients.

- ***Mixed type project:*** These projects include both design and production stages. Since the company requires comparatively much more time to reach the level of manufacturing due to longer design phases of defense sector, the lifecycles of this type of projects are generally longer, usually between 5 and 10 years. Non-repetitive operations such as design verification and qualification with related costs are incurred in design stage, whereas production stage requires repetitive costs, like labor and direct material costs. The reason for the company to conduct mixed type projects is to be able to manufacture the pre-designed final products that are almost available for serial production.

Project identification code: A unique 4-digit number is employed to represent each project like 7895, 8945.

Project operation stages: One project can include at most two stages, which are described as below:

- ***Design stage:*** Experience, capacity and specialized labor are essential for this stage. R&D operations are implemented initially due to absence of necessary know-how and capability to meet project requirements. Potential risk factor for this stage is relatively higher, and therefore the company tries to manage impacts of unexpected costs. Besides, the most of the costs associated with this stage are defined as non-repetitive costs which the company does not expect to encounter in the later stages of the project or the projects related to the designed product.

- ***Production stage:*** Manufacturing and related activities are pursued for production of semi-finished or final products in line with the final product tree and the associated requirements. Operations and their related costs are of repetitive type in contradistinction to dominant cost type in design stage which is non-repetitive. Production stage is relatively smooth and straightforward in terms of operation management, and as a result possible risks are relatively less in this stage.

Project currency: There is not a specific currency for all of the projects. The preferences of the client for a project specify the currency type to be used in the contract. Currency types most frequently deployed in projects of the company are Turkish Lira (TRY), Euro (EUR), US Dollars (USD) and Pounds (GBP). It is possible to employ more than one currency type for a project.

Project currency term is especially significant for the company, since all payments and advances defray accordingly. Moreover, exchange rates can give rise to financial risks due to differences between project currency and the currency of the project expenses. Therefore, this term gives rise to several risk considerations which the company has to deal with.

Project cost factors: These cost factors only include costs related with project activities, which means that operations of the company not involved in project processes are not taken into account. Costs factors can be classified such as:

- Labor (divided according to semi products all of which require special expertise)
  - Technician (such as avionics assembly, computer missile assembly, fuel assembly, X-ray)
  - Engineer (such as avionics, missile computer, fuel)
- Material (such as raw, semi-finished, freight, insurance)
- Inventory
- Outsourcing
- Investment
- Travel
- Training
- Warranty term.

Work Breakdown Structure (WBS): Project management team defines distinct work units during the project lifecycle in order to make them more manageable, and these work units can be designed for any activity carried out by the company.

This tool provides simplicity while managing project activities, since it ensures cost planning and control as well as providing guidance for schedule development and control (Project Management Institute, 2006).

Project work plan: Division of work units to sub-units and scheduling of these sub-units are completed in accordance with WBS as the first step for creating a project work plan. Thereafter, each sub-work element is assigned to the responsible personnel under the related cost center. Formation of project work plan is conducted at the very start of the project. However, this work plan is alterable to keep up with possible derivations in any operation due to several reasons such as logistics disruptions or personnel allowances. To manage these alterations, regular meetings from different responsible departments are carried out for projects during their lifecycles.

Project financial plan: To meet the requirements of a project on time without violating the financial constraints, the company creates a financial plan based on the work plan. Any activity including financial essence is evaluated in this plan. Payment schedule is also covered in the financial plan. Generally, a defined percentage of the bid price is taken from the customer as an advance payment to initiate the operations that need a certain lead time such as supply of direct materials and machines, and hiring processes for extra labor requirements. Pro-advance payments are taken gradually over time as defined in the related contract. Financial plan plays an important role in financial risk management process, hence the company follows an attentive manner when preparing this plan to prevent herself from unexpected future financial losses.

Delivery quantity: The delivery quantity with specified delivery time is an important matter for the company because of the fact that it determines the supply chain strategy of the company for the related project. Since delivery quantity is a compulsory factor from which serious penalty costs may result, it is specified in the contract between the customer and the company.

Defense sector is highly dependent on the government policies and political issues, and therefore it is possible that the customer may want an alteration in the delivery quantity throughout the project lifetime. Changes in delivery quantity can also be a result from an internal factor. However, available change interval for the delivery quantity is mostly determined in the contract to clarify the allowable limits of change.

Supplier selection: Supplier selection is carried out for the necessary project elements, such as materials in the product tree, or services for which the company does not have enough time or experience. Supplier relations and cost are the main factors considered in the supplier selection processes to eliminate the vulnerabilities resulting from logistics disruptions to some extent at least.

Also, there are governmental restrictions for the national projects to increase the national sub-industry and hence become more compatible in the market. Herewith, the company has to satisfy the pre-determined supply requirements, if such conditions exist in the contract (Balkan 2010).

3.2. The Generation of Bid

Bid preparation phase is a step that the company really takes very seriously to maximize her profit as well as the probability of winning. Since the trade-off between the profit and the probability of winning endures, the main goal of the company becomes to refrain from possible financial and market share losses.

Main operations to be employed during bid preparation process are business development/marketing, market research and benchmarking, meetings with customers, characterization of the customer demands, job and activity analysis, historical data analysis, design and modeling, budgeting, pricing and declaration of the final bid price (Balkan, 2010).

Each of the aforementioned activities needs to be carried out by the responsible personnel specialized in the related area. Therefore, the bid determination team is appointed in order to identify the responsible personnel and to get through a much more organized and manageable bid preparation process. Otherwise, the bidding process would fail at the very beginning.

Bid determination team: Selection of the bid determination team is an essential activity in the bidding process. The team effort and the proficiency of the team members have an important effect on the project proposal. The contribution of team members directly influences the capability level of the proposal team and so the success of the bid determination process. Therefore, this team is expected to be consisting of experienced personnel that are aware of the company's capacity and expectations. Hence, the management relies on the personnel who can distinguish the bids or projects that can create value for the company. The bid determination team includes the members specified as follows (Balkan, 2010):

- ***Project Manager:*** This person takes upon the main responsibility on himself/herself in both the financial and technical management of a project. Meetings with customers are mostly held under the guidance of the project manager.

- ***Bid Responsible:*** Business Development and Marketing Department is the actual actor undertaking the role of bid responsible. During the bid determination process, these personnel are responsible for all preparatory activities, and they directly report to the project manager. They define the bid determination schedule by appointing responsible groups to related work packages. WBS, work plan and financial plan preparation activities are also conducted by this department. In the final stage of the bid preparation, these personnel finalize the bid price.

- ***Technical Responsible:*** All technical activities carried out within the scope of a project are executed by the related technical personnel. One project requires more than one technical responsible most of the time, since the projects in the defense industry require a blend of several disciplines for the satisfaction of the technical requirements. Technical areas in the context of the company might be quality, fuel, conceptual design, technical design, and system design. These functional departments assign a technical plan including tests and evaluation activities with the required job descriptions.

- ***Financial Responsible:*** All finance related activities such as workforce cost computations, inflation and exchange rate estimations, and escalations in material and energy consumption are reflected to the bid by financially responsible personnel. Financial terms substantially include risks due to uncertainty, and therefore financial predictions are made after a detailed analysis is done to avoid from possible financial losses.

- ***Production Responsible:*** All operations related to the production of any kind of semi-finished material are assigned to a production responsible with a production team. Production departments are organized according to the technical requirements for production operations of the company such as captive seeker, avionics, fuel, etc.

The bid team can always ask for the opinion of the other departments that are not directly members of the bid preparation team asks for. For example, Production Planning Department is frequently asked for an advice about additional materials handling and storage requirements for a candidate project.

Cost factors of the company: Cost factors for all activities carried out by the company are previously determined and open for selection by any project. Detailed cost element types of the bid and cost elements used in both stages of the project - design and production stages- are as in Figure 6.

- ***Labor:*** The costs of all types of wages used on account of a project make up the labor costs for a project. These costs are categorized as engineering and technician, based on the departmental requirement differences.

- ***Investment:*** The investments only required for the project such as additional construction, and purchase of machines, tool, license and software, etc. constitute the investment costs for a project. It is possible for the company not to be able to use project specific investments other than the specified project. Hence, investment costs are an important portion of the costs for a project.

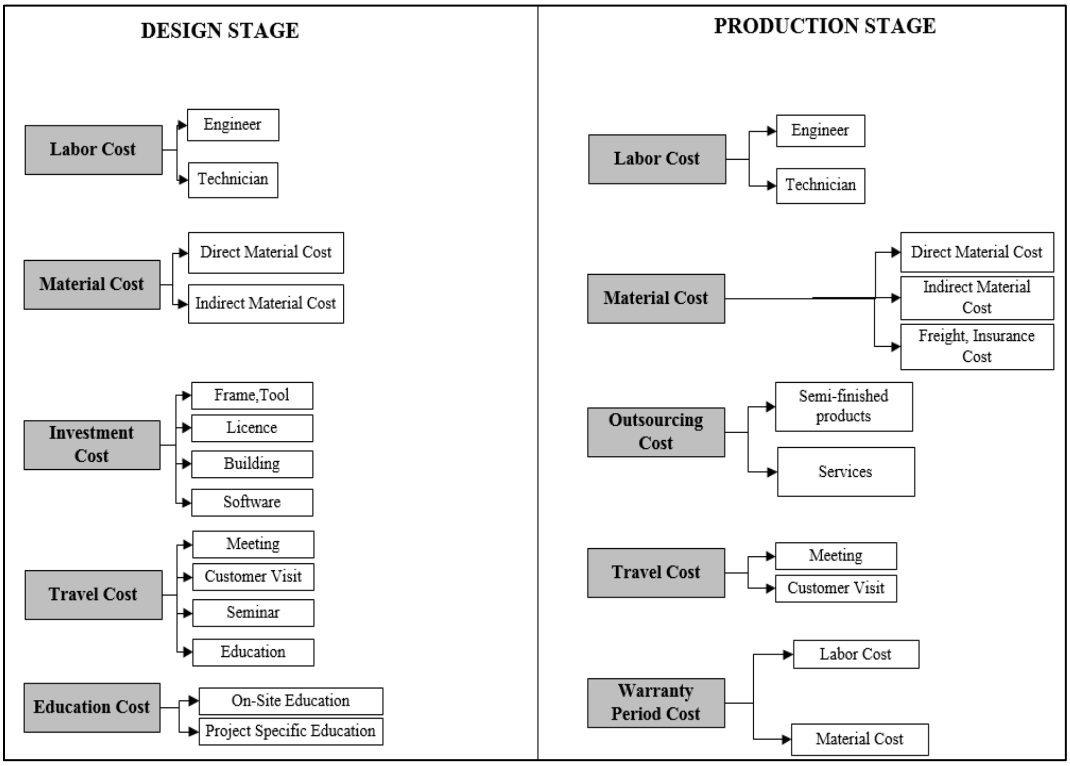


Figure 6 Bid Cost Collecting (Balkan, 2010)

- ***Material:*** Required materials with the associated quantities for any project-related activity constitute this cost type. If the materials to be purchased are obtained by considering already existing product trees or from the experience of the related personnel, this information is used to define the necessary material and the related material costs for the project. Otherwise, the material cost for a project is only an estimation made by relying on the market value of the material group. These blind presumptions for material costs are mostly made for non-recurrent design stages of new products which do not resemble any other existent product.

  Purchasing Department defines several suppliers to obtain the cost of a specified material and make an analysis with historical data and benchmarking, and hereafter makes estimation for material cost. During the cost estimation process, all material related costs occurring in the supply chain such as freight and insurance are also included in the material cost.

Scrap rate and discount rates are also very important consideration factors while calculating the material cost.

- ***Outsourcing:*** One of the main factors in the strategic plan of the company is to become a leader in the defense sector by decreasing the number of non-value added operations and increasing the level of technology and complex operations requiring high technology. Consequently, the company prefers subcontractors to supply some semi-finished products, if it is more cost effective and not against security obligations of the company and the customer. Therefore, the company makes several make or buy decisions are by considering interior and exterior requirements with the most cost effective way possible.

- ***Education:*** It is not always possible to acquire every technical detail and know-how of the entire defense sector. Consequently, additional knowledge about which the company does not already have can be required for a new project. In this case, this inadequacy is eliminated as soon as possible by outsourcing the necessary education, and conferences from external resources

- ***Travel:*** Any travelling activity related with the project is scheduled and included in pricing regardless of its content.

- ***Warranty:*** The warranty period duration is usually defined in the contract. The company is responsible to perform all necessary actions on the product which the customers already have in their inventory and make the product efficiently operating until the end of warranty period. An update on the software of the product or resolution of quality-related deficiencies can be examples of the actions which can be implemented during warranty period. These actions also require the usage of labor and material, and hence related costs to these items are estimated and specified in the contract.

Generation of the bid cost: It is mandatory to prepare the WBS for every project and assign the associated work packages to the departments for the beginning of the bid cost generation process. Financial responsible personnel provides all cost factors specified above to all involved departments and henceforth individual departments pick up the cost factors they will possibly hold through the lifecycle of the project.

Following the completion of cost collection from the related departments, bid responsible determines the bid price with the support of financial responsible. While determining the bid price, there are certain steps to be employed by the company as follows:

- ***Cost scheduling:*** Cash flows for all types of cost items growing out of the project, whether they are repetitive or not, are scheduled by the project management responsible in accordance with the work plan and the financial plan, following the completion of cost collection from each department assigned to project.

- ***Exchange and inflation rate (escalation) estimations:*** Finance Department gets in touch with several financial organizations including banks to collect necessary input required in the estimation process. Then, the department forms an analysis for exchange and inflation rates over the project lifetime to be able to reflect the changes in these rates to the bid price to some extent by using previous years' realizations and future estimations.

  Inflation and exchange rate predictions are employed to calculate both labor and material costs, and so these predictions are to be made systematically to prevent from possible profit losses due to erroneous cost estimations at least to some extent.

- ***Labor cost escalation factor:*** As any other commodity in the market, labor costs fluctuate based on inflation. As a result, inflation rate predictions directly have an impact on the labor rate. Thence, yearly labor escalation rates are estimated by the finance department by considering the currency effect and inflation estimations.

- ***Raw material price escalation factor:*** Material costs undulate repeatedly, but they are more inclined to increase. This escalation has its repercussions on financial gain of the project. While determining the estimation for raw material price escalation, data from official sources are used.

- ***Labor Cost:*** Finance Department determines the unit labor rate in national currency using the cost data for past years prior to project start date. Sub-units of labor cost can be seen in Figure 7 (Balkan, 2010).

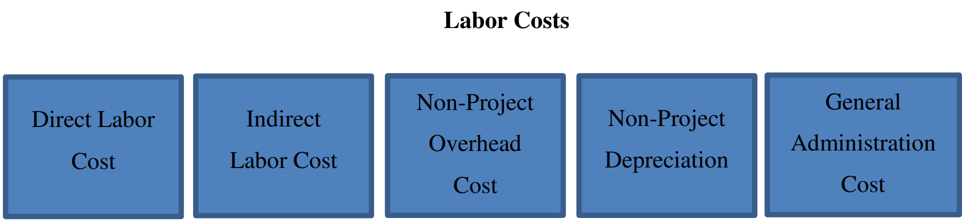


Figure 7 Labor Cost Elements

As each cost center is placed into the work plan, the required project-related labor hour for each period is predicted, then labor hour prediction for each cost center is multiplied with the associated unit labor rate, and consequently periodical labor cost for each cost center is acquired in national currency.

- ***Cost Conversion:*** The difference between the costs in national currency and the costs in other currencies can result in difficulties for financial project management. It is then crucial to synchronize the cost data in different currencies after the cost collection for eliminating financial risks.

- ***Cash Flow:*** All financial activities are finalized before composing the cash flow regarding the payment plan of the contract. In the cash flow, there are generally one advance payment at the beginning of the project and several progressive payments according to the work plan schedule.

- ***Financial Costs:*** Finance Department presumes financial costs or profits considering the cash flows. If an uncertainty is estimated by this department for any period, a certain financial amount is budgeted to eliminate it as much as possible.

Bid price cost determination process of the company can be summarized as in Figure 8.

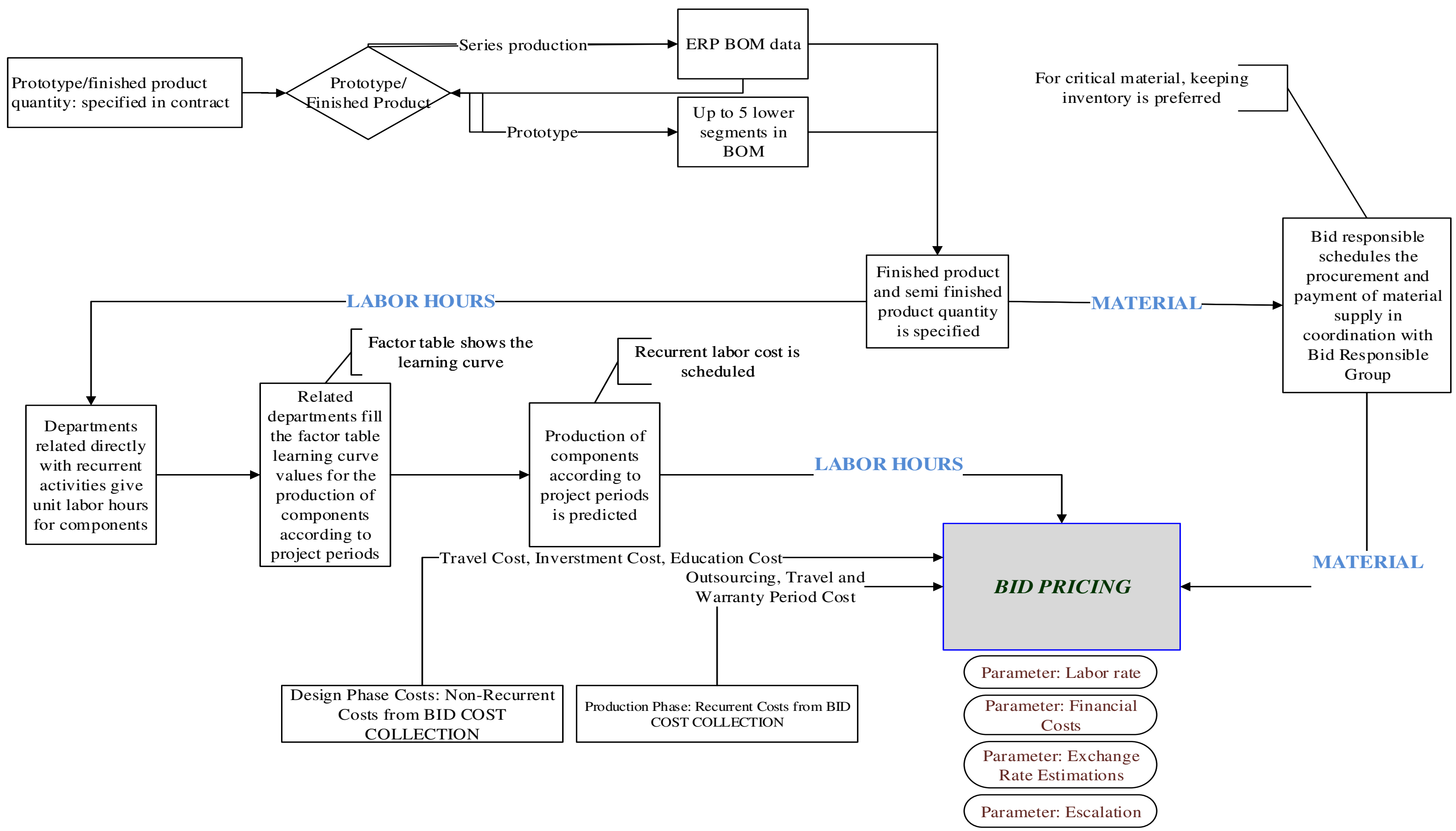


Figure 8 Determination of the Recurrent Costs and Cost Scheduling of the Company (Balkan, 2010)

- ***Markup:*** This term is fixed in the contract, but the sides -the company and the customer- are free to make negotiations and certain arrangements with a common understanding before signing the contract. The position of the company among the competitors heavily affects the position of the company in this bargaining process.

By considering all steps of bid pricing activities in above, the bid pricing process of the company is shown with a schematic representation in Figure 9 (Balkan, 2010).

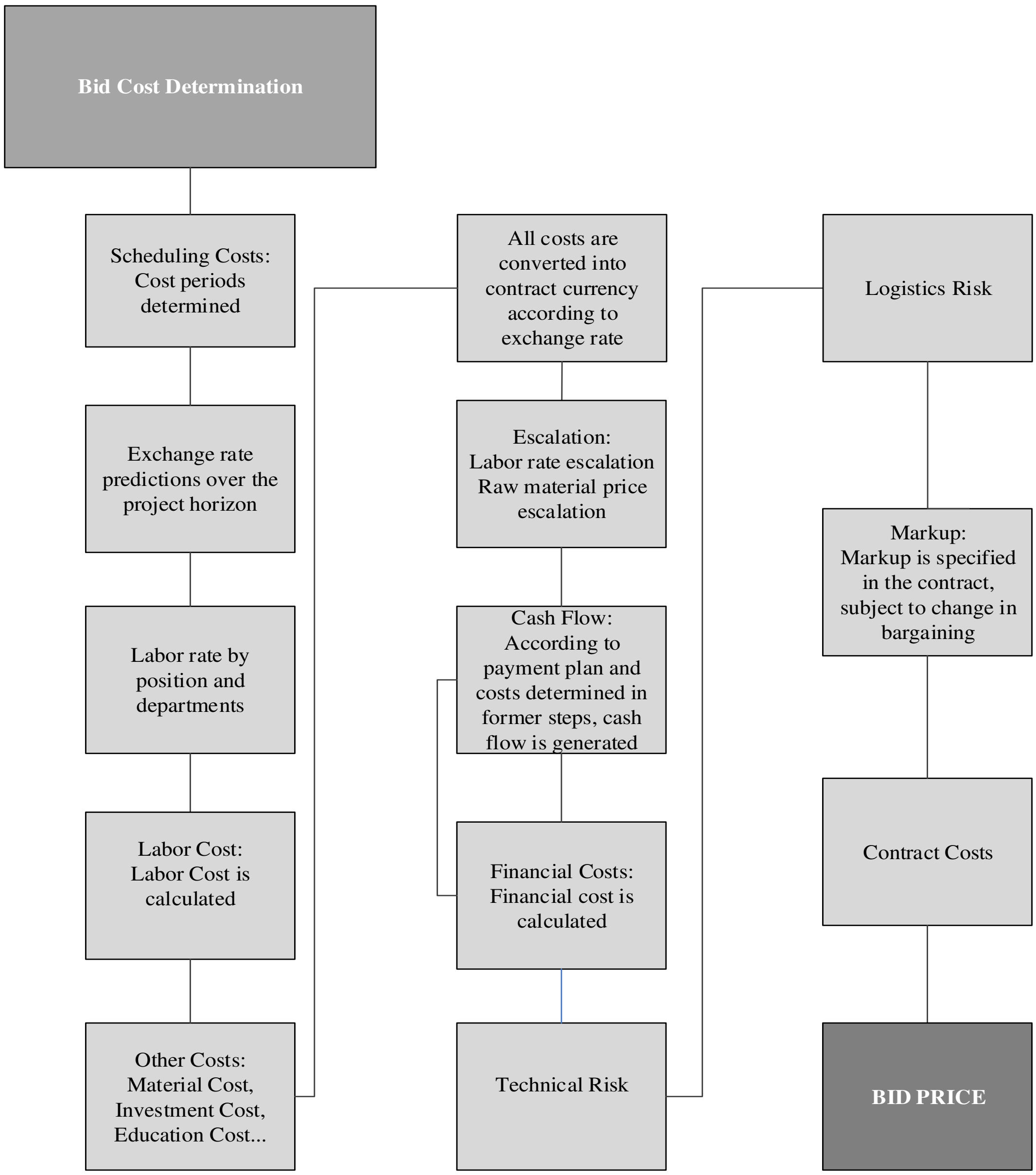


Figure 9 Bid Pricing Activities

- ***Contract Cost:*** The percentage for contract cost is the same for all projects and generally defined as 5% of total project cost.

3.3. The Problem Context

The evaluation of risk level for a project is tricky and it has to be separately executed for each project which has different characteristics. The company should handle the evaluation process carefully to prevent from any possible damage to the financial status of the company and the shareholders. Since the bid price determination process is itself quite straightforward and more or less the same for every project of the company, then the main problem to tackle with becomes the identification of risk factors and their effect on profitability for a project.

At this point, it is possible to categorize risks of the company for a project into three main categories as:

3.3.1. Technical Risks

Any element having impact on labor units should be considered as a risk factor. Exceeding budgeted work hour due to material supply, investment or any other element mean a technical risk for projects. However, the capability of the company to fight against any possible technical risk determines the importance level of that risk for a project.

The project characteristics help the management to pick up one of three possible technical risk levels. Production projects generally contain low technical risks, yet R&D projects include relatively higher technical risk levels as medium or high according to the customer's requests. Hence, experiences show that the company is exposed to technical risk at three different levels which increase the estimated work-hours in percentages: low (0%), medium (5%) and high (10%).

3.3.2. Logistics Risks

Logistics risks reflect any kind of disruption in material supply. Delays in deliveries and project deadlines due to disruptions in logistics result in logistics risks for the company. Logistics risks depend on risk level of individual materials in BOM, vendors and the ability of the company to deal with logistics issues.

For a project, the appropriate logistics risk levels are chosen according to the project characteristics. Similar to technical risk level selection, logistics risk level is accepted minimum for the project which the company familiar with such as production projects. Higher risk levels for logistics are chosen, on the other hand, if the company expects several uncertainties as in R&D projects. Then, the company has generally three logistic risk levels which decrease the amount of material to be supplied in a period in percentages: low (0%), medium (-5%) and high (-10%). There might be some cases that delay in material supply is more frequent than specified, but it would just be an unordinary case.

3.3.3. Financial Risks

Due to uncertainty in financial predictions, financial risks, more or less, are likely to occur for each project of the company. As a result of the errors in financial estimations, the budget defined by the company for a project can be exceeded. Then, financial risks can lead to violation of the contracted bid budget.

Since market parameters change independently from the company, and the company does not have any direct effect on these uncontrollable parameters, the company should get its guard in order not to suffer from the variability of these parameters. The only way to avoid from these risk factors is to pay attention to them at the very beginning of the bidding process through the bid price, because it is impossible to make price changes due to financial factors after the contract is signed.

By considering these three main risk types specified above, it is clear that a risk-oriented approach is needed to maximize the financial gain of the company and the wealth for shareholders when determining the bid price of a project. Therefore, we focus on finding the best bid price while maximizing the value added to the company prone to technical, logistics and financial risks via robust optimization method and implement two-stage stochastic programming as stated by Birge and Louveaux (1997). Thence, scenario-independent structural variables-'here-and-now' decisions- and scenario-specific control variables -'wait-and-see' decisions- are used in the model. Also, to make a clear distinction between project utility attributes and so to be able to conceive a decision-support tool for the company, the objective function of the model includes a total utility function (Hahn and Kuhn, 2012).

As aforesaid, the financial risk in the context of this study can be defined as the deviations in exchange and inflation rate estimations. Logistics risks due to disruptions and erroneous estimations for labor hour are also included to reflect the uncertainty in the labor hour estimation for especially in R&D projects and changes in the labor hour as a result of disruptions in supply chain. Our purpose is to build a risk-driven robust optimization model so as to maximize total project utility attribute. Our model is tested with several generated scenarios including different parameters, and then the outputs of the model for these parameters are examined in detail by also comparing with the results of Balkan (2010) for the same company.

Estimated scenarios only one of which is pessimistic are employed in the model to pursue robust optimization approach. Our model is designed to be employed as a part of the decision support system of the company providing that projects obtain the maximum level of total economic value added for the company. While doing that, financial and supply chain related uncertainties and the impact of these risks when determining optimum bid price and probability of winning are examined in detail. Furthermore, we focus on solution robustness for our model to achieve that a certain level of closeness to optimality is guaranteed in 'almost' every scenario (Scholl, 2001).

CHAPTER 4

VALUE-BASED RISK MANAGEMENT WITH A ROBUST OPTIMIZATION APPROACH

A mixed integer robust optimization model is developed in this chapter. The model reflects the perspective of the management: whether he/she is willing to take risks for a candidate project. With regard to the management perspective, our model is constructed to acquire the optimum bid price for a project through the maximization of the utility function.

To begin with, a description of the problem environment and the assumptions we make in the solution process are presented to draw a clear framework of the problem.

4.1. Problem Environment

The company works for both make-to-order and engineer-to-order manufacturing for projects in the defense sector. Since the company works based on projects that start with winning a bid, bidding process is taken very seriously by the management.

Thence, first of all the assumption to not to accept workforce decisions affecting the bid price of the company is diminished in this thesis as opposed to Balkan (2010) by considering the fact that they in fact affect the bid price to reach more realistic decisions for the problem environment of the company. The reason for this additional attention of our model is that workforce decisions actually have an important impact on project profitability by not itself but with risk elements to which they cause. Hence, the most effective way to change profitability is through bid price by considering workforce decisions in bid price preparation process. Also, another factor missing in the previous study is the effect of disruptions in logistics to bid price. Delays in material supply lead to both overtime and excess time in terms of labor, but more importantly they can bitterly result in penalties and so reduce the expected gain and destroy the reputation of the company. By including these two factors excluded in the previous study, we try to achieve a more realistic model for the company.

In the physical domain of the company, production capacity can be extended or decreased using overtime, firing and hiring new personnel to be able to meet project requirements as aforementioned. However, this alteration brings out some extra costs related to change in capacity elements. Despite the flexibility in production capacity, bid price of a project is fixed due to long-term contract, and so financial gain of the project is highly affected by how the company employs this flexibility. Therefore, physical domain constitutes an important element for the bid pricing problem.

Considering the financial domain of the model, short-term financial investments and borrowings with interest are considered for every period and these short-term borrowings cannot exceed a specified level of credit. These financial elements are considered only for the bid project under consideration in our model, that is, we do not include these financial elements for other projects of the company in the model which considers only one project at a time. Accounts receivable includes the progressive payments from customers to the company at the end of each period, but the company can seldom prefer early payment by offering a cash discount in the payments. Same approach is also valid for accounts payable to suppliers. The company can make early payments to suppliers to obtain a discount through negotiation. Accounts receivable for factoring and accounts payable for early payment generally can be employed to balance liquidity level in a period. Also, the effect of inflation on Net Present Value (NPV) is another important factor to consider in terms of the financial domain.

4.2. Model Assumptions

Contracting:

1. Frequently used contracting methods in the sector are given in the literature section. By taking into account the competitive environment the company is in, current legal requirements and the contracting operations of the company, we can definitely presume that the company uses Firm-Fixed-Price contracting method (Balkan, 2010).

Capacity:

2. Long term assets of the company are presumed to be adequate, however, expansions in these assets for extra project requirements are allowed if required. Therefore, the project-specific extra investment costs are allowed to be covered in the proposed bid price.
3. Additional requirements related to the land can be established in the company's current land supposed to be ample enough.
4. Overtime work hours cannot exceed 10% of the total work hours available in a period.

Labor and supply chain:

5. Both engineering and manufacturing labor are used in the company.
6. Manufacturing labor includes any effort related to production. Production engineer and production technician are the main personnel of manufacturing labor that include all labor types related to production operations and quality as well. These manufacturing labor types require a smooth supply chain to be functional, that is, delays in material supply affect the use of manufacturing labor.
7. Engineering labor is not directly affected from logistics disruptions.
8. Labor types can be categorized in detail according to sub-assembly that they work for. Each labor generally specializes in a sub-assembly such as avionics, rocket fuel, etc. and normally it is not possible to transfer a personnel among labor groups of other subassemblies.
9. Each department determines her labor rate meticulously through the bid cost preparation process by getting average of the related labor costs, which the financial department has already computed.

10. Budgeted material percentage for any material type to be supplied and budgeted labor percentage for any labor type to be used in a period are always more than the planned percentage of delivery of final product for a specific period. Delays in material supplies can result in both delay in deliveries of final product and fluctuations in labor usage sometimes with overtime and sometimes with under time.

11. Delay at the end of the project lifecycle, that is, the final delivery, is strictly not allowed due to higher penalty rates comparing with the penalty rates of intermediate deliveries. Required (planned) work hour estimation for labor types and supplied material percentages are determined by taking this fact into account. The company tries to utilize its labor resources and supply the materials in the BOM in such a way that risks causing delays in the final delivery are totally eliminated. Then, all materials are supplied before the last period no matter what to guarantee that any project is finished at the end of the project lifecycle.

12. Technical risk includes erroneous labor hour estimation and the additional labor requirements occurring due to delays in material supply. Deficiency or surplus in material supply is handled with logistics risk factor. The logistics risk is defined as the percentage of material which cannot be supplied in a period or the percentage of material which cannot be processed with the extra labor hours by creating technical risk due to operational constraints.

Cash flow and delivery:

13. The payments made by the customers in each period are incorporated as a reward into the model. Due to this fact, financial cost of the project becomes a risk free element and it is accepted as a cost parameter. Then, financial cost is a budget constraint in the model.

14. Raw material and labor cost values escalate as based on the inflation rate over the project lifecycle.

15. Project progressive payments during each period are accepted to be made at the end of the period.

16. Deliveries are made at the end of periods, if any and delivery quantities are determined in the contract.

17. Government fund is assumed to be taken at the end of the project lifecycle when all cash flows have already occurred. Therefore, government fund is not included in cash-flow equations and accepted as non-monetary benefit in the model.

4.3. The Robust Optimization Model

Robust optimization methods are used to eliminate the effects of risk as much as possible because of supply chain and financial uncertainties, and to obtain the most resilient results for the bid pricing problem under every possible circumstance.

Our robust value-based performance and risk management model finds the optimum bid price for a project by taking into account the management's risk-level preference for the project. Data for technical and logistics risk, inflation and exchange rate are obtained as a discrete scenario set with specified probabilities to conduct robust optimization model.

The bid price selection decision has to be modeled before the actual scenario realization as a 'here-and-now' decision. In other words, the decisions except the bid price selection such as all other labor and the financial decisions can be left over to the second step as scenario-specific 'wait-and-see' variables (Hahn and Kuhn, 2012).

4.3.1. Sets

S	Set of scenarios $1,\ldots,n_s$
T	Set of project time periods in years $1,\ldots,n_t$
I	Set of material types $1,\ldots,n_i$
K	Set of labor types $1,\ldots,n_k$
BP	Set of bid price alternatives *LBP*,..., *HBP* (*LBP*=Lowest Bid Price-probability of winning (pow) is 1, *HBP*=Highest Bid Price- pow is 0)

4.3.2. Parameters

There are two different types of parameters used in the model: given parameters and calculated parameters.

Given Parameters

P_s	Probability of occurrence for scenario *s*
$INF_{s,t}$	Inflation rate estimation with scenario *s* for year *t* in national currency
$EXCH_{s,t}$	Exchange rate estimation with scenario *s* for year *t*
$INT_{s,t}$	Market interest rate estimation with scenario *s* in year *t* in project currency (Assumed to be inflation rate of for national currency and scenario *s* in year *t* plus 1,5% / exchange rate estimation for scenario *s* in year *t* and $INT_{s,0}$ is equal to zero)
TR_s	Technical risk due to erroneous labor-hour estimation and delayed material supply for scenario *s*
LR_s	Logistics risk estimation for materials which cannot processed with overtime or supplied less than expected for scenario *s* in the required period
$MC_{i,0}$	Unit material cost of material type *i* at the beginning of the project in national currency (at time zero)
TSM_i	Total projected amount of material *i* to be supplied over the project lifecycle
$PM_{i,t}$	Projected percentage of material type *i* to be supplied in period *t*
TL_k	Total projected labor unit needed for labor type *k* over the project lifecycle
$PL_{k,t}$	Projected percentage of total labor hour for labor type *k* that will be used in period *t*
$PP_{k,t}$	Number of planned personnel for labor type *k* in period *t*
$LC_{k,0}$	Unit labor cost of labor type *k* at the beginning of the project in national currency (at time zero)
$LMA_{i,k}$	$\begin{cases} 1, \text{if labor type } k \text{ is related with material } i \\ 0, \text{o.w.} \end{cases}$
BPR_{bp}	Bid price value of the bp^{th} alternative
$PPAY_t$	Payment percentage from customers for year *t* according to the payment plan (payments made in project currency)

PEN_t	Penalty cost for one unit of final product delayed in period t in project currency
INV_t	Budgeted investment cost in national currency in period *t*
INC_t	Budgeted investment cost in project currency in period *t*
OC_t	Budgeted other costs in national currency period *t* (travel, education, etc.)
OCC_t	Budgeted other costs in project currency in period *t*
PD_t	Percentage of planned delivery of final product in period *t*
REF	Reference of the company during the bid process
POW_D	Scaling parameter for probability of win function
C	Number of the competitors for the project (1, if none)
BQ	Quantity of the bid (total delivery size)
$SDMAX$	Maximum amount of debt, 20000000 (determined by the company)
$OCOST$	Cost rate for the overtime of personnel per hour Overtime wages are 1.5 times the normal wages, and then *OCOST* is set to constant coefficient, 0.5 (Balkan, 2010).
$SCOST$	Cost rate for surplus as a result of hired personnel, 0.5 (Balkan, 2010)
$FCOST$	Cost rate for the fired labor Compensation payment for fired personnel is the total amount of salary for one year, then *FCOST* is equal to $MC_{k,s,t}$ WH (Balkan, 2010).
$HCOST$	Cost rate for the hired personnel Due to learning curve effect, it takes 3 months for hired personnel to work efficiently. *HCOST* is then determined as 0.25 of unit labor cost in a period (Balkan, 2010).
Z	Tax rate, 0 for defense sector
IHR	Hurdle rate, 0.015 (determined by the company)
FD	Factoring discount rate for incoming customer payments, 0.04 (Hahn and Kuhn, 2012)
CD	Factoring early payment for debt to suppliers, 0.02 (Hahn and Kuhn, 2012)

IFI	Interest rate for short term investments, 0.002 (Hahn and Kuhn, 2012)
IDS	Interest rate for short term debts, 0.007 (Hahn and Kuhn, 2012)
GF	Government funding rate of the project, between 0 and 0.6
MS	Market share effect, between 0 and 5
$PSUC$	Probability of success defined separately for each project
$PSUC\_A$	Scaling factor A of technical risk function
$PSUC\_B$	Scaling factor B of technical risk function
$PSUC\_C$	Scaling factor C of technical risk function
$PSUC\_ACC$	Minimum acceptable level for probability of technical success
RUN_POW	Run parameter for probability of win
RUN_PSUC	Run parameter for probability of success
$BIGM$	Big number, 10000
$BIGN$	Big number, 1000000000000
REF_ROEVA	Reference rate of EVA, 0.15 (determined by the company)
WH	Work hours per year per worker (assumed to be 2000 hours)
W_MS	Weight of market share impact, 0.417 (determined by the company)
W_GF	Weight of government funding, 0.235 (determined by the company)
W_EVA	Weight of rate of upside potential of EVA, 0.348 (determined by the company)
γ	Risk function parameter in the objective function
FIN	Financial cost of managing the project given as a parameter
HBP	Highest bid price

Calculated Parameters

$MC_{i,s,t}$ Unit material cost of material type *i* for scenario *s* in period *t* in national currency

$$MC_{i,s,1} = MC_{i,0}, \qquad \forall i \in I, \forall s \in S$$

$$MC_{i,s,t+1} = MC_{i,s,t}\left(1 + INF_{s,t}\right), \qquad \forall\, i \in I, \forall s \in S, \forall t \in T \backslash \{5\}$$

$LC_{k,s,t}$ — Unit labor cost of labor type *k* for scenario *s* in period *t* in national currency

$$LC_{k,s,1} = LC_{k,0}, \qquad \forall k \in K, \forall s \in S$$

$$LC_{k,s,t+1} = LC_{k,s,t}\left(1 + INF_{s,t}\right), \qquad \forall k \in K, \forall s \in S, \forall t \in T\backslash\{5\}$$

$DPM_{i,s,t}$ — Desired percentage of material *i* to be supplied for scenario *s* in period *t* (updated according to scenario realization at the beginning of each period)

$$DPM_{i,s,1} = PM_{i,1}, \qquad \forall i \in I, \forall s \in S$$

$$DPM_{i,s,t+1} = PM_{i,t+1} - RPM_{i,s,t} + DPM_{i,s,t}, \qquad \forall i \in I, \forall s \in S, \forall t \in T\backslash\{5\}$$

$RPM_{i,s,t}$ — Real percentage of material *i* supplied for scenario *s* in period *t* (affected by logistics risk)

$$RPM_{i,s,1} = DPM_{i,s,1}\left(1 + LR_s\right), \qquad \forall i \in I, \forall s \in S$$

$$RPM_{i,s,t+1} = \begin{cases} DPM_{i,s,t+1}\left(1 + LR_s\right), & DPM_{i,s,t+1} < \left(1 - \sum_{j=1}^{t} RPM_{i,s,j}\right) \\ 1 - \sum_{j=1}^{t} RPM_{i,s,j}, & DPM_{i,s,t+1} \geq \left(1 - \sum_{j=1}^{t} RPM_{i,s,j}\right) \end{cases}$$

$$\forall i \in I, \forall s \in S, \forall t \in T\backslash\{5\}$$

$BW_{k,t}$ — Required total labor hour for labor type *k* in period *t*

$$BW_{k,t} = TL_k\, PL_{k,t}, \qquad \forall k \in K, \forall t \in T$$

$RPML_{i,k,s,t}$ — Real percentage for material *i* used for labor type *k* for scenario *s* in period *t*

$$\sum_{j=1}^{t} RPML_{i,k,s,j} = \begin{cases} bigM, & LMA_{i,k} = 0 \\ \sum_{j=1}^{t} LMA_{i,k}\; RPM_{i,s,j}, & LMA_{i,k} = 1 \end{cases}$$

$$\forall i \in I, \forall k \in K, \forall s \in S, \forall\, t \in T$$

$RPL_{k,s,t}$ Real percentage of labor type *k* used for scenario *s* in period *t*

$$\sum_{j=1}^{t} RPL_{k,s,j} = argmin\left(i, \sum_{j=1}^{t} RPML_{i,k,s,j} \right), \qquad \forall i \in I,$$
$$\forall k \in K, \forall s \in S, \forall t \in T$$

$RLU_{k,s,t}$ Real labor units used of labor type *k* for the realization scenario *s* in period *t*

$$\sum_{j=1}^{t} RLU_{k,s,j} = (1 + TR_s)\, min\left(\sum_{j=1}^{t} BW_{k,j}, TL_k \sum_{j=1}^{t} RPL_{k,s,j} \right),$$
$$\forall k \in \forall K, s \in S, \forall t \in T$$

$RWF_{k,s,t}$ Extra required workforce level of labor type *k* for scenario *s* in period *t* (in hours)

$$RWF_{k,s,t} = \begin{cases} 0, & (PP_{k,t}\, WH - RLU_{k,s,t}) \geq 0 \\ PP_{k,t}\, WH - RLU_{k,s,t}, & (PP_{k,t}\, WH - RLU_{k,s,t}) < 0 \end{cases}$$
$$\forall k \in K, \forall s \in S, \forall t \in T$$

$PPR_{s,t}$ Percentage of produced final product for scenario *s* in period *t* =Final production quantity under scenario *s* at the end of period *t*/Bid quantity

$$\sum_{j=1}^{t} PPR_{s,j}$$
$$= min\left(argmin\left(k, \sum_{j=1}^{t} RPL_{k,s,j} \right), argmin\left(k, \sum_{j=1}^{t} PL_{k,j} \right) \right),$$
$$\forall k \in K, \forall s \in S, \forall t \in T$$

$IN_{i,s,t}$ Ending inventory level of material *i* for scenario *s* in period *t*

$$IN_{i,s,0} = 0, \qquad \forall i \in I, \forall s \in S$$
$$IN_{i,s,t} = TSM_i \left(\sum_{j=1}^{t} RPM_{i,s,j} - min\left(\sum_{j=1}^{t} PD_j, \sum_{j=1}^{t} PPR_{s,j} \right) \right),$$
$$\forall i \in I, \forall s \in S, \forall t \in T$$

$IC_{s,t}$ Change in total inventory level value for scenario *s* from period *t*-1 to period *t*

$$IC_{s,t} = \frac{\sum_i IN_{i,s,t}\ MC_{i,s,t}(1+INF_{s,t}) - IN_{i,s,t-1}\ MC_{i,s,t}(1+INT_{s,t})}{EXCH_{s,t}}, \qquad i \in I, \forall s \in S, \forall t \in T$$

$COST_s$ Expected financial cost for scenario *s*

$$COST_s = FIN + \sum_t (\sum_i \frac{PM_{i,t} TSM_i MC_{i,s,t}}{EXCH_{s,t}} + \sum_k \frac{PL_{k,t} TL_k LC_{k,s,t}}{EXCH_{s,t}} + INC_t + OCC_t + \frac{(INV_t + OC_t)}{EXCH_{s,t}}) / \prod_{j=1}^{t} (1 + INT_{s,j-1}), \qquad i \in I, k \in K, \forall s \in S, t \in T$$

R_PSUC Risk function of probability of success (Balkan, 2010)

$$R\_PSUC = \begin{cases} PSUC\_A - (e^{-PSUC/PSUC\_C}\ PSUC\_B), & RUN\_PSUC = 1 \\ PSUC\_A - (PSUC\ PSUC\_B\ /PSUC\_ACC), & RUN\_PSUC = 2 \\ PSUC\_A - (PSUC\_B) PSUC^{\ PSUC\_C}, & RUN\_PSUC = 3 \end{cases}$$

U_MS Utility of market share impact

$$U\_MS = MS/5$$

U_GF Utility of government funding

$$U\_GF = GF/0.6$$

POW_{bp} Probability of winning with the bid price *bp*

$$POW_{bp} = min\left(max\left(1 - \left((1 - REF) e^{\frac{(HBP-bp)^2}{(HBP^2/POW\_D)}}\right)(C)^{0.25}, 0\right), 1\right), \qquad \forall bp \in BP$$

The last equation for probability of winning shows the probability of winning as a function of the bid price. The constitution of this function is quite complicated especially in the existence of competitors, even though the number of possible competitors in defense industry is relatively less than other sectors. Therefore, the probability of winning function is determined by holding interviews with the related personnel in the company to be able to reflect the company's environment to the model in the best way possible. It is seen that the capacity of the company, the number and capability of competitors, the reference factor as a consequence of former business relations, industry participation and offset factor, and last and most important of all, offered price play an important role while determining probability of winning.

As it is also stated in the literature part, price is a significantly determinative factor for probability of winning. Furthermore, markup is also another consideration while determining probability of winning. According to Naert and Weverberg (1978) and Friedman (1956), a function for probability of winning can be formulated making use of both cost estimate and markup. At below, cost and markup functions for probability of winning are shown in Figures 10 and 11 where σ_x is the uncertainty level (Naert and Weverberg, 1978; Friedman, 1956).

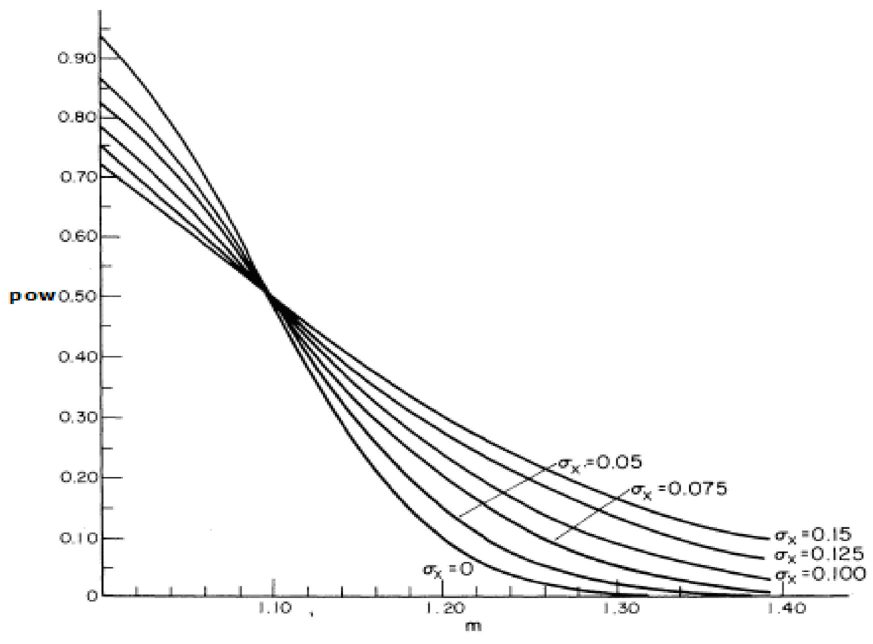


Figure 10 Markup (m) Based Probability of Win Function

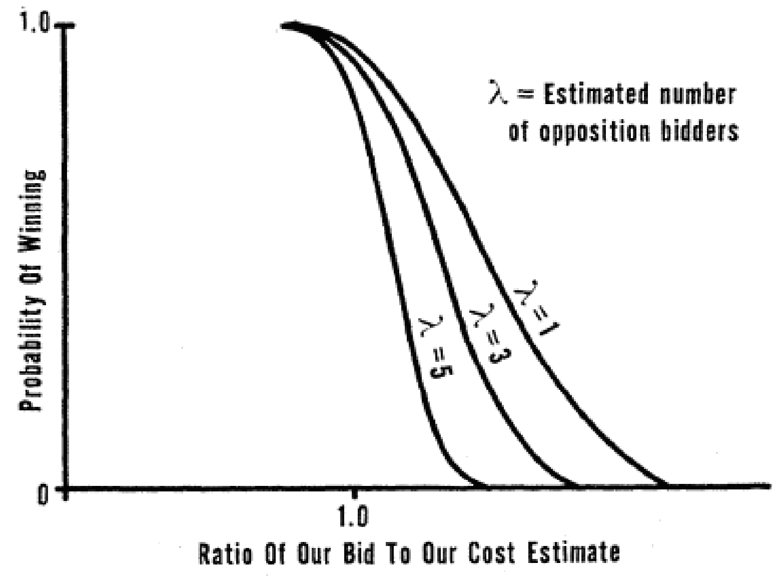


Figure 11 Cost Based Probability of Win Function

Then, our probability of winning function contains three main factors as a scale factor *D*, reference factor *REF* and the number of competitors *C* by considering both the problem environment of the company and the previous study. The probability of winning function for our problem under consideration can be formed as (Balkan, 2010):

$$pow(bp) = 1 - \left((1 - ref) e^{\frac{(HBP - bp)^2}{(HBP^2/d)}} \right) (C)^{0.25}, \quad \forall bp \in BP$$

To create probability of winning functions for the projects of the company, the factors used in the function are determined by cooperating with the bid responsible. Based on the Naert-Weverberg's approach and Friedman's probability of win function shape, 12 probability of winning functions are demonstrated in Figures 12 and 13 in terms of the level of probability of winning environment for a project having *LBP*=60 and *HBP*=80 (Balkan, 2010).

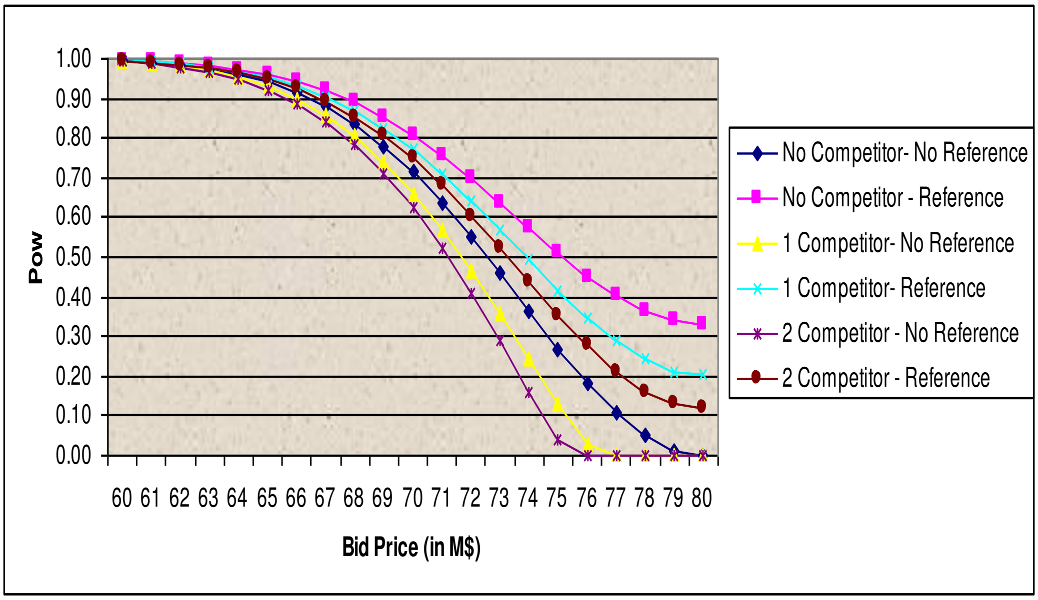


Figure 12- pow for 6 Different Situations (d=-80, high pow environment)

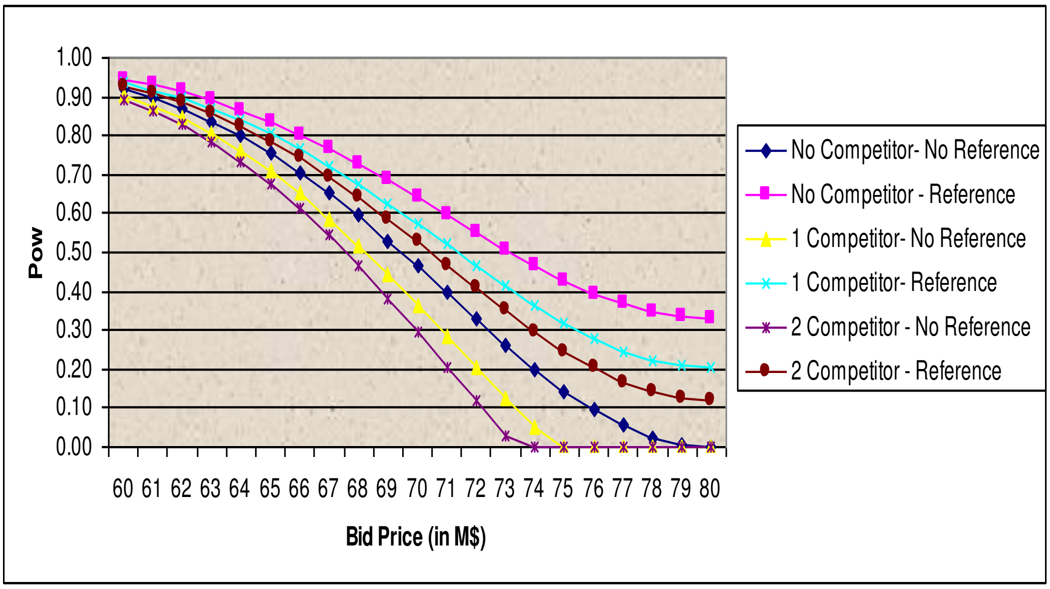


Figure 13- pow for 6 Different Situations (d=-40, low pow environment)

Probability of technical success is determined according to chosen run type. Allowed interval for probability of technical success has found to be 60% to 100% by the management, and functions are formed by considering this limitation. Run type 1 represents a risk-seeking decision maker with a concave risk function, whereas run type 2 represents a risk-neutral decision maker with a linearly decreasing risk function. Risk-averse feature of decision maker is represented by run type 3 through a convex risk function.

4.3.3. Decision Variables

x_{bp} — $\begin{cases} 1, \text{if bid pice } bp \text{ is selected} \\ 0, \text{o.w.} \end{cases}$

$w_{bp,k,s,t}$ — Workforce level for bid price *bp* of labor type *k* for scenario *s* in period *t*

$o_{bp,k,s,t}$ — Overtime labor unit for bid price *bp* of labor type *k* for scenario *s* in period *t*

$h_{bp,k,s,t}$ — Number of hired personnel for bid price *bp* in labor type *k* for scenario *s* in period *t*

$f_{bp,k,s,t}$ — Number fired of personnel for bid price *bp* in labor type *k* for scenario *s* in period *t*

$s_{bp,k,s,t}$ — Surplus hour for bid price *bp* of labor type *k* for scenario *s* in period *t*

$sn_{bp,k,s,t}$ — Surplus hour due to hired personnel for bid price *bp* of labor type *k* for scenario *s* in period *t*

$eva_{bp,s}$ — Economic Value Added for bid price *bp* and scenario *s*

$deva_{bp,s}$ — Negative fraction of EVA for bid price *bp* and scenario *s*

$ueva_{bp,s}$ — Positive fraction of EVA for bid price *bp* and scenario *s*

$r\_ueva_{bp,s}$ — Rate of upside EVA for bid price *bp* and scenario *s*

$r\_deva_{bp,s}$ — Rate of downside EVA for bid price *bp* and scenario *s*

$ur\_ueva_{bp,s}$ — Utility rate of upside EVA for bid price *bp* and scenario *s*

eur_ueva_{bp} — Expected value of utility rate of upside EVA in terms of bid price *bp*

$pd_{bp,s}$ — Penalized part of upside EVA in terms of the difference between expected utility value of upside potential of EVA and real upside potential of EVA for bid price *bp* and scenario *s*

$nr_{bp,s,t}$	Net revenue as the difference between payments from customers and costs for penalty, inventory and miscellaneous activities for bid price *bp* and scenario *s* at the end of period *t*
$fi_{bp,s,t}$	Position in financial investments for bid price *bp* and scenario *s* at the end of period *t*
$nop_{bp,s,t}$	Net operating profit of the project for bid price *bp* and scenario *s* at the end of period *t*
$co_{bp,s,t}$	Variable cost of operations related to labor and material cost in addition to accounts payable for early payment and early account receivable for bid price *bp* and scenario *s* in period *t*
$noa_{bp,s,t}$	Net operating assets due to project for bid price *bp* and scenario *s* at the end of period *t*
$\delta_{bp,s}$	Binary variable used for finding negative and positive fraction of EVA providing that they are not positive at the same time for bid price *bp* and scenario *s*
$\beta_{bp,k,s,t}$	Binary variable to make sure that hiring and firing cannot be made at the same time for bid price *bp,* labor type *k* and scenario *s* in period *t*
$fm_{bp,s,t}$	Financial management amount due to financial investments and short-term borrowings for bid price *bp* and scenario *s* at the end of period *t*
$oi_{bp,s,t}$	Open items for management due to the difference between payment and early payment to suppliers and the difference between payment and early payment from customers for bid price *bp* and scenario *s* at the beginning of period *t*
$cf_{bp,s,t}$	Open cash flow from operations as a result of labor, project investments and other miscellaneous activities for bid price *bp* and scenario *s* in period *t*
$ar_{bp,s,t}$	Accounts receivable from the customers for bid price *bp* and scenario *s* at the end of period *t*
$ar^{-}_{bp,s,t}$	Amount of accounts receivable from the customers for factoring for bid price *bp* and scenario *s* in period *t*

$ap_{bp,s,t}$	Account payable to the suppliers for bid price *bp* and scenario *s* at the end of period *t*
$ap^{-}_{bp,s,t}$	Amount of accounts payable to the suppliers for early payment for bid price *bp* and scenario *s* in period *t*
$sd_{bp,s,t}$	Short term debts for bid price *bp* and scenario *s* at the end of period *t*

MODEL

$$Max \sum_{bp} POW_{bp}\ R\_PSUC\ \left(\sum_{s} P_s\ W\_EVA\ ur\_ueva_{bp,s} + x_{bp}\ (W\_GF\ \ U\_GF + W\_MS\ \ U\_MS) - \gamma\ P_s\ \left(pd_{bp,s} + r\_deva_{bp,s}\right)\right) \quad (0)$$

s.t

$$w_{bp,k,s,t} = WH\left(x_{bp}\ PP_{k,t} + \sum_{j=1}^{t} h_{bp,k,s,j} - \sum_{j=1}^{t} f_{bp,k,s,j}\right), \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \quad (1)$$

$$o_{bp,k,s,t} \leq 0.1\ w_{bp,k,s,t}, \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \quad (2)$$

$$sn_{bp,k,s,t} = RWF_{k,s,t}\ x_{bp} + o_{bp,k,s,t} + WH\left(\sum_{j=1}^{t} h_{bp,k,s,j} - \sum_{j=1}^{t} f_{bp,k,s,j}\right), \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \quad (3)$$

$$RLU_{k,s,t}\ x_{bp} = w_{bp,k,s,t} + o_{bp,k,s,t} - s_{bp,k,s,t}, \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \quad (4)$$

$$h_{bp,k,s,t} \leq \beta_{bp,k,s,t}\ BIGM, \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \quad (5)$$

$$h_{bp,k,s,t} \leq x_{bp}\ BIGM, \qquad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \tag{6}$$

$$f_{bp,k,s,t} \leq \left(1 - \beta_{bp,k,s,t}\right) BIGM, \qquad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \tag{7}$$

$$f_{bp,k,s,t} \leq x_{bp}\ BIGM, \qquad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \tag{8}$$

$$nr_{bp,s,t} = x_{bp}\left(BPR_{bp}PPAY_t - \left(PEN_t\, max\left(0, \left(\sum_{j=1}^{t} PD_j - \sum_{j=1}^{t} PPR_{s,j}\right)\right)\ BQ + \left(INC_t + OCC_t + \frac{(INV_t + OC_t)}{EXCH_{s,t}}\right)\left(1 + INT_{s,t}\right)\right)\right), \qquad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{9}$$

$$noa_{bp,s,t} = x_{bp}\sum_{i}\frac{IN_{i,s,t}MC_{i,s,t}\left(1 + INF_{s,t}\right)}{EXCH_{s,t}} + ar_{bp,s,t} + \sum_{j=1}^{t}\left(oi_{bp,s,j}\left(1 + INT_{s,j}\right) - cf_{bp,s,j}\left(1 + INT_{s,j}\right) + fm_{bp,s,j}\right) - ap_{bp,s,t}, \qquad i \in I, \forall bp \in BP, \forall s \in S, \forall t \in T \tag{10}$$

$$eva_{bp,s} = ueva_{bp,s} - deva_{bp,s}, \qquad \forall bp \in BP, \forall s \in S \tag{11}$$

$$ueva_{bp,s} \leq \delta_{bp,s}\ BIGN, \qquad \forall bp \in BP, \forall s \in S \tag{12}$$

$$deva_{bp,s} \leq \left(1 - \delta_{bp,s}\right) BIGN, \qquad \forall bp \in BP, \forall s \in S \tag{13}$$

$$co_{bp,s,t} = \frac{\sum_i x_{bp}\ RPM_{i,s,t}TSM_i MC_{i,s,t}}{EXCH_{s,t}} + \frac{\sum_k x_{bp}RLU_{k,s,t}\ LC_{k,s,t}}{EXCH_{s,t}} + \frac{\sum_k LC_{k,s,t}\left(WH\left(f_{bp,k,s,t}\ FCOST + h_{bp,k,s,t}HCOST\right)\right)}{EXCH_{s,t}} + \frac{\sum_k LC_{k,s,t}\left(\left(sn_{bp,k,s,t}SCOST + o_{bp,k,s,t}OCOST\right)\right)}{EXCH_{s,t}} - ap^{-}_{bp,s,t}CD + ar^{-}_{bp,s,t}FD, \qquad i \in I, k \in K, \forall bp \in BP, \forall s \in S, \forall t \in T \tag{14}$$

$$nop_{bp,s,t} = nr_{bp,s,t} - co_{bp,s,t}\left(1 + INT_{s,t}\right) + x_{bp} IC_{s,t}, \qquad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{15}$$

$$BPR_{bp}\, PPAY_t\, x_{bp} - PEN_t\, max\left(0, \left(\sum_{j=1}^{t} PD_j - \sum_{j=1}^{t} PPR_{s,j}\right)\right) BQ - ar_{\overline{bp},s,t}^{-} - ar_{bp,s,t} = 0, \qquad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{16}$$

$$x_{bp} \frac{\sum_i RPM_{i,s,t} TSM_i MC_{i,s,t}}{EXCH_{s,t}} - ap_{\overline{bp},s,t}^{-} - ap_{bp,s,t} = 0, \quad i \in I, \forall bp \in BP, \forall s \in S, \forall t \in T \tag{17}$$

$$cf_{bp,s,t} = \frac{\sum_k x_{bp} RLU_{k,s,t}\, LC_{k,s,t}}{EXCH_{s,t}} + \frac{\left(\sum_k LC_{k,s,t}\, WH\left(f_{bp,k,s,t}\, FCOST + h_{bp,k,s,t}\, HCOST\right)\right)}{EXCH_{s,t}} + \frac{\left(\sum_k LC_{k,s,t}\left(sn_{bp,k,s,t} SCOST + o_{bp,k,s,t}\, OCOST\right)\right)}{EXCH_{s,t}} + x_{bp}\left(INC_t + OCC_t + \frac{(INV_t + OC_t)}{EXCH_{s,t}}\right), \quad k \in K, \forall bp \in BP, \forall s \in S, t \in \forall T \tag{18}$$

$$oi_{bp,s,t} = ar_{bp,s,t-1} + ar_{\overline{bp},s,t}^{-}(1 - FD) - ap_{bp,s,t-1} - ap_{\overline{bp},s,t}^{-}(1 - CD), \quad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{19}$$

$$sd_{bp,s,t} \le x_{bp}\, SDMAX, \qquad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{20}$$

$$fi_{bp,s,t} \le x_{bp} BPR_{bp} PPAY_t\,, \qquad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{21}$$

$$fm_{bp,s,t} = fi_{bp,s,t-1}(1 + IFI) - fi_{bp,s,t} - sd_{bp,s,t-1}(1 + IDS) + sd_{bp,s,t}, \quad \forall bp \in BP, \forall s \in S, \forall t \in T \tag{22}$$

$$eva_{bp,s} = \sum_{t} \frac{nop_{bp,s,t}(1-Z) - noa_{bp,s,t-1}\left(1+INT_{s,t}\right)IHR}{\prod_{j=1}^{t}\left(1+INT_{s,j}\right)}, \quad (23)$$

$$\forall bp \in BP, \forall s \in S, t \in T$$

$$r\_ueva_{bp,s} = \left(\frac{ueva_{bp,s}}{COST_s REF\_ROEVA}\right), \qquad \forall bp \in BP, \forall s \in S \quad (24)$$

$$ur\_ueva_{bp,s} \leq r\_ueva_{bp,s}, \qquad \forall bp \in BP, \forall s \in S \quad (25)$$

$$ur\_ueva_{bp,s} \leq 1, \qquad \forall bp \in BP, \forall s \in S \quad (26)$$

$$r\_deva_{bp,s} = \left(\frac{deva_{bp,s}}{COST_s REF\_ROEVA}\right), \qquad \forall bp \in BP, \forall s \in S \quad (27)$$

$$eur\_ueva_{bp} = \sum_{s} ur\_ueva_{bp,s} P_s\,, \qquad \forall bp \in BP, s \in S \quad (28)$$

$$pd_{bp,s} \geq 0, \qquad \forall bp \in BP, \forall s \in S \quad (29)$$

$$pd_{bp,s} \geq eur\_ueva_{bp} - ur\_ueva_{bp,s}, \qquad \forall bp \in BP, \forall s \in S \quad (30)$$

$$\sum_{bp} x_{bp} = 1\,, \qquad bp \in BP \quad (31)$$

$$\sum_{j=1}^{t} (oi_{bp,s,j}\left(1+INT_{s,j}\right) - cf_{bp,s,j}\left(1+INT_{s,j}\right) + fm_{bp,s,j}) \geq 0, \quad (32)$$

$$\forall bp \in BP, \forall s \in S, \forall t \in T$$

$$noa_{bp,s,0} = 0; ar_{bp,s,0} = 0; ap_{bp,s,0} = 0; fi_{bp,s,0} = 0; sd_{bp,s,0} = 0, \quad (33)$$

$$\forall bp \in BP, \forall s \in S$$

$$w_{bp,k,s,t}, o_{bp,k,s,t}, h_{bp,k,s,t}, f_{bp,k,s,t}, s_{bp,k,s,t}, sn_{bp,k,s,t}, deva_{bp,s}, ueva_{bp,s}, r\_ueva_{bp,s}, ur\_ueva_{bp,s}, r\_deva_{bp,s,} eur\_ueva_{bp}, fi_{bp,s,t}, ar_{bp,s,t}, ar^{-}_{bp,s,t}, ap_{bp,s,t}, ap^{-}_{bp,s,t}, sd_{bp,s,t} \geq 0, \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \tag{34}$$

$$x_{bp}, \delta_{bp,s}, \beta_{bp,k,s,t} \in \{0, 1\}, \quad \forall bp \in BP, \forall k \in K, \forall s \in S, \forall t \in T \tag{35}$$

In the model, the objective function considers the maximization of the sum of the utilities for certain bid project attributes as the market share effect, the rate of EVA and the government funding multiplied by probability of success and probability of winning. Firstly, single attribute utility functions are used when finding the utility of each project attribute, and after that a multiple attribute utility function is used to combine these three independent utilities according to their relative importance weights. Hence, we reach the total utility for the bid project. The robust parameter in the objective function let the management personnel to reflect their perspective against risk by affecting the offered optimum bid price value. At this point, we can explain the similarities and differences between our study and Balkan (2010) which considers the bid pricing problem of the same company in terms of the models. Firstly, we consider labor related decision variables in the model while determining the optimum bid price. However, labor-related decisions are accepted as given in the model of Balkan (2010) and they only create a penalty for the bid price. In addition, logistics risk is considered in our proposed model as different from the study of Balkan (2010). Also, we prefer to use rate of EVA instead of ROR by again differentiating from the model perspective of Balkan (2010). Despite these differences, both studies try to find the optimum bid price within a given interval by using the similar utility attributes through the use of a multi-attribute utility function. Penalizing the model with different robustness levels is also employed in both studies, although the penalized robustness parts differ from each other. The model of Balkan (2010) penalizes the deviation from the expected ROR, whereas our model penalizes both the difference between the expected utility of upside potential of EVA and the utility rate of upside potential, and the utility of downside potential of EVA.

Constraints 1-8 determine the labor-related decision variables. Since we compare our study with the study of Balkan (2010), we prefer to use the same decision variables as much as possible in terms of these decision variables. Workforce level for each bid price, labor type and scenario is calculated by Constraint 1 in every period. For each bid price, labor type and scenario, Constraint 2 assures that allowed overtime cannot exceed 10% of the available workforce level in a period. Surplus as a consequence of hired personnel is calculated for each bid price, labor type, scenario and period through Constraint 3. Constraint 4 defines the main capacity considerations in terms of each labor type and period by considering the related bid price and scenario. If a bid price is chosen among the alternatives, real labor unit for a labor type and a specific scenario in a period must be met by related work force and overtime by excluding any surplus. Hence, Constraint 4 satisfies this requirement.

Constraints 5-8 ensure that the number of hired and fired personnel cannot be bigger than zero for any labor type, scenario and period, if a bid price is not chosen at all. Also, these two variables cannot be bigger than zero at the same time, that is, the company cannot both hire and fire for the same labor type during a period. Extreme circumstances such as suspension from work or other extreme conditions are not evaluated in the context of this thesis.

EVA related decision variables are computed by using a similar approach with Hahn and Kuhn (2012). Net revenue for each scenario and bid price for every period is considered in Constraint 9 as the difference between revenues of progressive payments and the costs of investment, penalty and other activities planned in that period. More explicitly, this constraint covers the predetermined payment percentage of the bid price, penalty costs due to logistics delays and the predetermined costs for investments and other budgeted costs to define the net revenue at the end of a period. At this point, it is remarkable to state that fixed penalty costs which linearly increases with the number of delayed deliveries arise only from logistics delays.

In Constraint 10, net operating assets any for bid price and scenario at the end of each period cover the inventory level of each material with the related unit material cost, accounts receivable, and cash position as a result of open items for management with the related interest rate, financial management and cash flow from operations with the related interest rate by subtracting accounts payable to suppliers.

Constraints 11-13 are used to calculate EVA with the related upside and downside parts for each bid price and scenario. Binary variable δ assures that either upside or downside potential of EVA can be bigger than zero at a time. These three constraints are quite important for the model, since robust optimization approach is provided by these constraints.

Constraint 14 takes into account costs of operations for each scenario and bid price during a period. This constraint includes purchasing, overtime, firing, hiring and surplus labor costs due to hired personnel in addition to factoring losses. The purchasing costs consist of real material quantity supplied for any bid price, scenario and period evaluated with the real material cost of that product. The labor costs are derived from real labor unit used, and extra costs for hiring, firing, overtime and surplus due to hired personnel for any bid price, scenario in a period by using actual labor cost in the specific scenario and period. The amount of accounts payable for early payment at the beginning of the period with a discount rate is considered as a gain for the period, then this amount is deducted from variable costs. The amount of accounts receivable from the customers with a discount rate is added as a cost on the other hand.

Constraint 15 determines total contribution margin for each bid price and scenario in any period based on the net revenues from the project and variable costs of operations. Variable costs are multiplied with an interest rate to reflect time value of the money. The change in the inventory level for every scenario in a period is also added as an additional contribution to total contribution margin.

Constraints 16 and 17 calculate the amount of accounts receivable from the customers for factoring and the amount of accounts payable to the suppliers for early payment for each bid price and scenario in a period by considering the progressive payment income from customers occurring at the end of the period and material purchase during the period. The amount of accounts receivable and the amount of accounts payable to the suppliers then cover the balance of remaining accounts receivable and payable for each bid price and scenario at the end of the period (Hahn and Kuhn, 2011).

Cash flow from operations for each bid price and scenario in a period is derived by considering payments for labor costs in that period by Constraint 18. Expenses for labor activities are a combination of real labor unit used for each labor type, overtime costs for that period, hiring and firing costs and surplus cost due to newly hired personnel. Payments for investments and other costs in both national and project currency are also considered in this constraint as a cash flow.

Constraint 19 calculates open items for management by considering the accounts receivable from the previous period and early accounts receivable in the period with the effect of discount rate by deducting cash flows from the current period as a result of accounts payable to the suppliers in the previous period early accounts payable to customers in the period by considering a discount rate.

Maximum level of short term debt is limited to *SDMAX* in Constraint 20, if a certain bid price is chosen. Otherwise, it is not possible get any debt for a non-chosen project price. Also, the level of financial investment cannot be higher than the selected bid price payment for the period, as it is defined in Constraint 21.

Constraint 22 derives the status of financial management considering short-term financial investments and short-term borrowings for each bid price and scenario at the end of a period with financial investments and the short term debts in the previous period and their related interests.

Constraint 23 evaluates EVA for each bid price and scenario. According to Kaplan and Atkinson (1998), *EVA* for bid price *bp* for scenario *s* is conceptually calculated as Net Operating Profit after Tax (NOPAT) minus total costs of invested capital in Net Operating Assets (NOA) at the end of the previous period *t-1* considering weighted average cost of capital i^{wacc}.

$$EVA_t = NOPAT_t - NOA_{t-1} \cdot i^{wacc}$$

In our model, NOPAT results from net operating profit *nop* for bid price *bp* and scenario *s* in period *t* with the effect of tax rate *Z*. The capital charge on the other hand is derived from net operating assets *noa* for bid price *bp* and scenario *s* at the end of previous period *t-1*with related hurdle rate *IHR* as NOA. After calculating these values at the end of each period, the model finds the NPV of EVA for bid price *bp* and scenario *s* by using cumulative inflation rate for scenario *s* considering time *t*.

Constraint 24 determines the utility of upside EVA for each bid price and scenario return before by considering the scenario related cost of the project and reference rate of EVA determined by company authorities. Constraints 25 and 26 ensure that utility rate of positive utility rate of EVA cannot be bigger than 1 in any case. Constraint 28 defines the utility rate of downside potential EVA as equal to downside EVA divided by the scenario related project cost. This rate is allowed to be bigger than 1, because this portion does not create any value for shareholders but destroys it. Therefore, we aim to avert from downside portion of EVA as much as possible by letting this rate to be more than 1.

Constraint 28 calculates the expected value of upside portion of EVA for bid price *bp*. Constraints 29 and 30 then determine the amount of the deviation from the expected upside potential rates of EVA for each bid price and scenario to these deviations in the objective function and the non-negativity of the deviations.

Constraint 31 satisfies the condition that one and only one of bid price alternatives can be chosen to satisfy the model requirements. Constraint 32 requires that cash position is non-negative in each period. Constraint 33 provides that $noa_{bp,s,0}$, $ap_{bp,s,0}$, $ar_{bp,s,0}$, $fi_{bp,s,0}$, $sd_{bp,s,0}$ are all equal to zero.

Finally, nonnegative domain is assured by Constraint 34 for related finance related and labor decision variables, and Constraint 35 states binary variables.

Then, our model can be solved according to Constraints 1-35. The number of binary variables is equal to |BP|+|BP|x|S|+|BP|x|K|x|S|x|T|. The number of continuous variables is equal to 6|BP|x|K|x|S|x|T|+6|BP|x|S|x|T|+6|BP|x|S|+|BP|. The number of unrestricted continuous variables is equal to 7|BP|x|S|x|T|+|BP|x|S|. The number of constraints is equal to $14|BP|x|K|x|S|x|T|+18|BP|x|S|x|T|+20|BP|x|S|+|BP|+1$, and the number of binary constraints is equal to $|BP|x|K|x|S|x|T|+|BP|x|S|+|BP|$. Hence, the number of the decision variables and constraints which determine the size of the model depend on the project features which affect the model set. For example, a project which has an available bid price interval of 75 to 100 for 5 year project duration, no technical risk and 10 different labor types has 19,916 binary variables, 131,066 continuous variables, 14,040 unrestricted continuous variables. Also, there are 315,927 constraints and 19,916 binary constraints for this example case.

CHAPTER 5

GENERATION OF RISK SCENARIOS

Due to the robust structure of our solution approach, generation of risk scenarios is extremely important. This scenario generation phase requires much attention in terms of reliability and accuracy of the output generated by the model. Hence, we need to clarify the scenario generation process we used in our modeling by considering both financial, technical and logistics scenarios which are independent from each other. The total number of scenarios generated is equal to 45, and we define three different risk factors as financial, logistics and technical.

5.1. Financial Scenarios

As a typical characteristic of long-term projects, the variability in the expected cost of a project is mainly due to the financial factors s such as fluctuations in both exchange and inflation rates. Due to the uncertainty created by these financial factors, companies have to make certain assumptions to be able to calculate the expected cost of a project. They need to make more realistic approximations for the monetary values and reflect these assumptions in their project management operations as much as possible to avoid possible financial losses. Otherwise, these financial terms can easily turn into financial risk factors that result in financial losses for companies. Hence, uncertainty in both exchange and inflation rates is accepted as the financial risk factor in the scope of our proposed approach.

Project duration is assumed to be five years for each project. Although the similar study of Balkan (2010) includes 15 financial scenarios, we make a change in the number of financial scenarios by reducing their variety from 15 to 5, because we include an additional risk factor into the scenario generation, that is the logistics risk, with 3 different levels.

While generating the financial scenarios, we define the same probability for the extreme case scenario as in Balkan (2010). In this extreme scenario, exchange rate in terms of the currency code of the bid project does not increase at all until the end of the project lifecycle and consumer price index increases as the average of the other scenarios for interest rate. By considering this crisis scenario, we can include all financial possibilities into the model and measure the effects of unexpected conditions. However, this extreme scenario is not likely to occur in normal conditions, so a lower probability of occurrence is assigned to this scenario, which is 2% (Balkan, 2010).

We take the average values of the financial estimations in Balkan (2010) while generating the other 4 financial scenarios, so our study does not differ so much from the financial estimations of Balkan (2010). We group 14 individual scenarios of Balkan (2010) arbitrarily as in Table 4 and calculate inflation and exchange rate average values of each group to reduce the number of financial scenarios to four.

With this approach; we generate four different scenarios with equal probability of occurrences from year 2010 to 2014, and one extreme scenario having a lower probability of occurrence. Hence, we reach a total of 5 different financial scenarios. All 5 scenarios generated are listed in Table 4 as:

Table 4 Financial Scenario Descriptions

Scenario 1	• The averages of interest and exchange rate estimation values for the 6 different banks in September 2009 • The averages of interest and exchange rate estimation values for the 6 different banks in September 2009 increased with 5% in all rates • The interest and exchange rate estimations of Garanti Bank in September 2009 • The interest and exchange rate estimations of Garanti Bank in September 2009 increased with 5% in all rates
Scenario 2	• The interest and exchange rate estimations of TEB in September 2009 • The interest and exchange rate estimations of ING Bank in September 2009 • The interest and exchange rate estimations of HSBC Bank in September 2009 • The base inflation and exchange rate estimations in January 2010 with an escalation using their rate of change values between 2004 and 2009
Scenario 3	• The interest and exchange rate estimations of FORTIS Bank in September 2009 • The interest and exchange rate estimations of İşbank in September 2009 • The averages of interest and exchange rate estimation values for the Garanti Bank and İşbank in March 2010
Scenario 4	• The averages of interest and exchange rate estimation values for the Garanti Bank and İşbank in March 2010 increased with 5% in all rates • The interest and exchange rate estimations of İşbank in March 2010 • The interest and exchange rate estimations of Garanti Bank in March 2010
Scenario 5	• No increase in exchange rate and the average of all other inflation rate estimations (Unexpected crisis scenario)

Financial scenarios with related probabilities are given in Table 5.

Table 5 Financial Scenarios and Related Probabilities

Scenario	**Probability**
1	24.5%
2	24.5%
3	24.5%
4	24.5%
5	2%

Yearly inflation rate estimations and related probabilities for each scenario are given in Table 6.

Table 6 Scenario Estimation Values and Related Probabilities for Inflation Rate

		Inflation Rate (in year)				
Scenario	**Probability**	**2010**	**2011**	**2012**	**2013**	**2014**
1	24.5%	6.8%	6.3%	5.8%	4.9%	5.1%
2	24.5%	7.0%	7.1%	6.4%	6.1%	5.1%
3	24.5%	6.8%	6.1%	5.7%	4.1%	5.0%
4	24.5%	7.6%	5.0%	5.0%	8.0%	6.1%
5	2%	7.0%	6.9%	6.4%	6.0%	5.3%

Yearly USD exchange rate estimations and related probabilities each scenario are given in Table 7.

Table 7 Scenario Estimation Values and Related Probabilities for Exchange Rate (USD)

		Exchange Rate (in year)				
Scenario	**Probability**	**2010**	**2011**	**2012**	**2013**	**2014**
1	24.5%	1.56	1.66	1.64	1.73	1.89
2	24.5%	1.55	1.7	1.59	1.61	1.81
3	24.5%	1.56	1.59	1.58	1.63	1.7
4	24.5%	1.54	1.62	1.64	1.71	1.88
5	2%	1.46	1.46	1.46	1.46	1.46

5.2. Technical Risk Scenarios

The familiarity level of the company with a bid project defines the technical risk level, so we determine three levels of technical risk for projects of the company as similar to Balkan (2010): ‘no requirement for additional work hours’ with a probability of 50%, ‘5% more work-hours requirement’ with a probability of 30% and ‘10% more work-hours requirement’ with a probability of 20%. Production type projects generally fall into ‘no requirement for additional work hours’ category (Table 8).

Table 8 Scenarios for Technical Risk with Related Probabilities

Scenario	Probability	Value
No requirement for additional work-hours	50%	0%
5% more work-hours requirement	30%	5%
10% more work-hours requirement	20%	10%

5.3. Logistics Risk Scenarios

The delays in material supply define the logistics risk level and we determine three levels of logistics risk for projects of the company as ‘no delay’ with probability of 70%, ‘5% delay from the specified time period’ with probability of 20% and ‘10% delay from the specified time period’ with probability of 10% (Table 9).

Table 9 Scenarios for Logistics Risk with Related Probabilities

Scenario	Probability	Value
No delay	70%	0%
5% delay from the specified time period	20%	-5%
10% delay from the specified time period	10%	-10%

After completing the estimation of three different risk levels with the related probabilities, we associate five financial risk scenarios with three technical risk sand three logistics risk scenarios and we reach a total of 45 scenarios. Then, we determine the probability of occurrence for each scenario by using the associated probabilities of occurrence values of all three risk types.

CHAPTER 6

COMPUTATIONAL RESULTS

Our robust optimization model is developed by using GAMS version 23.5 and taking all necessary data from Microsoft Access Database 2013. All programs are run in Windows platform.

6.1. Base Case Project Selection

The company has a wide range of projects including different types, and for this reason we illustrate the model for three different projects with distinct characteristics in order to reflect the diversity of the project portfolio and also the responsiveness of our model to this diversity as much as possible. Then, the solutions obtained against various project characteristics are examined by considering the characteristic differences of these sample projects.

The first project is called as project CP which is an R&D project with a unique characteristic due to the substantial market share level utility for the company. The second project, GJ, is also another R&D project, but this project includes lower rates of market share and government funding. On the contrary to these two projects, the other project, PM, including almost no technical risk is an ordinary production type project and the company is familiar with the management and production operations of this type of project (Balkan, 2010).

Sample projects are chosen in such a way that the impact of the project attributes can be observed through the model outputs, since project attributes affect the utility function in the objective function. The attributes taken into account in the model are the rate of EVA, market share effect and government funding in addition to probability of technical success defined for each individual project. The last three attributes are assumed to be given as parameters whereas only the rate of EVA is defined by several factors such as the bid price value, costs and financial elements.

Through the analysis of the results in this study, there are several comparisons made with the study of Balkan (2010), which also examines the bid price process of the same company. One of the important reasons to choose the abovementioned sample projects is to be able to make better comparisons between our study and that of Balkan (2010) by using the same data. Only the data for project GJ is modified, but this revision is done for both the earlier and our study by decreasing the bid price range with a decrease in the delivery size from 8 units to 3 units to avoid computational complexity due to large range of bid price alternatives. We then develop an alternative approach to overcome this drawback our approach in terms of computational time. Hence, our model becomes capable of solving the bid pricing problem no matter what the size of the available bid price range is. We use the original data for project GJ to study the effects of this alternative approach.

The number of runs made in the earlier study by Balkan (2010) is decreased from 972 to 108 by eliminating two attributes not employed in our model: penalty term and form of utility function for the Rate of Return (ROR). The reason for elimination is that penalty term related to labor cost penalty is already handled inside our model and we can only use linear form of ROR, since our utility attribute, which is the rate of EVA (ROEVA), is a variable not a parameter.

The main features of the base case samples are in Table 10:

Table 10 Characteristics of the Sample Projects

Project	**Characteristics**				
	Probability of Success	***Market Share***	***Government Funding***	***Expected Cost (in M $)***	***Highest Bid Price (in M $)***
CP	0.85	4	0	60	80
PM	0.98	0	0	75	100
GJ (size=3 units)	0.8	1	0.1	120	160
GJ (size=8 units)	0.8	1	0.1	242	320

Project CP:

This project is a R&D type project and it requires certain design activities which the company is not very accustomed to. The company can benefit from the earlier experiences to some extent despite the lack of a direct familiarity, so the probability of technical success is not low as expected, compared to project GJ, and it is equal to 85%.

Since this project offers a new and unique product to the product portfolio of both the company and the sector, the company has a chance to improve her market position with this project. Hence, market share impact is defined relatively higher, as 4 out of 5. Although higher scores are obtained with regards to the technical success parameter and the effect of market share parameter, government funding is not available for this project due to the international customer profile. Expected project cost is around 60 M $, and the maximum allowable bid price is then equal to 80 M $.

Based on these features, this sample project gives us a chance to analyze the characteristics of a typical R&D project creating remarkable market share effect.

Project PM:

This project is dissimilar from the others in terms of the project type. PM is a production type project about which the company has a deep knowledge and capability. The project requires for several operations already conducted by the company in earlier projects, so the probability of technical success parameter is quite higher as being equal to 98%. Since the outputs of the project are not much innovative for the defense area, this project does not create a difference for the market share position of the company.

In addition, the government does not provide any financial support for this project due to lack of technology acquisition in production projects. Consequently, the company only aims to make some profit by operating this commercial project with minimum technical risk. The rate of EVA is then the only attribute to assess this project. Expected project cost is around 75 M $ and the maximum allowable bid price is then equal to 100 M $.

<u>Project GJ:</u>

This project is a pure R&D type project with which the company does not establish so much similarity. As a result, this project has a lower score for probability of technical success which is 80%. In terms of the market share effect, the project does not really make the company outclass against its competitors; hence it includes an effect of market share less than project CP, being equal to 1 out of 5.

Moreover, this project makes a considerable contribution for the national defense industry, and the main reason to start this project is to satisfy national defense requirements. As a result, the rate of available government funding is positive, which is equal to 10%. This project offers government funding and market share impact utilities as the most distinguishing feature. We study two different versions for this project, one of which is only for the development of an alternative approach due to limitations of our model. Expected cost of modified project GJ having product quantity of three is around 120 M $, and maximum allowable bid price is then equal to 160 M $. Expected cost of the original project GJ having product quantity of eight is around 242 M $, and so the maximum bid price is chosen as being equal to 320 M $.

Unless otherwise stated, project GJ refers to the version of project GJ having the delivery size of three units.

6.2. Parametric Analysis

Robustness terms and probability of win (pow) functions are analyzed using parametric analysis to examine the solutions and investigate the model behavior in the scope of different project characteristics and parameters. Model outputs are grouped by the robustness level described in Table 11.

Table 11 Solution Sets Description

Solution Set	Parameter Setting
Expected (Exp)	γ=0
Robustness 1 (R1)	γ=0.2
Robustness 2 (R2)	γ=0.4

We examine the model behavior against risk factors by considering the probability of win function and utility attributes as the rate of EVA (ROEVA), the market share impact and the government funding. Even though the rate of return is not a utility attribute for our study, we also calculate the related probabilities of being at the desired ROR level, which is 15% similar to the desired rate of EVA, of each offered bid price for each scenario. We hold 108 runs for each project, and Table 12 includes the details for these run-types.

Table 12 Factors for the Parametric Analysis

Parameter Definition	Alias	Parameter Level	Levels of parameters		
Form of Risk Function	psuc	3	Risk Seeking	Risk Neutral	Risk Averse
Probability of Win-Competitor	Pow	3	No Competitor	1 Competitor	2 Competitors
Probability of Win- Reference	Pow	2	No Reference	Reference	
Probability of Win-Environment	Pow	2	High pow	Low pow	
Model Parameters-Robustness	γ	3	γ=0	γ=0.2	γ=0.4
Total Parameter		**108**			

Although probability of success is another parameter of the model, the optimal bid price values are not defined by this parameter. Probability of success parameter is more proper to use for project portfolio selection decisions which is not the main aim of our model. Hence, no analysis is carried out for this parameter.

6.2.1. Parametric Analysis Results

For each project, the model outputs for the problem instances are grouped and examined in terms of robustness term parameter having 3 levels: $\gamma=0$, $\gamma=0.2$ and $\gamma=0.4$.

Characterization of robustness parameter

Since our aim is to see the impact of uncertainty level on the proposed model, we define the higher level for the robustness parameter as 0.4, assuming a very risky problem environment, and minimum robustness parameter level as 0, assuming a problem environment with no-risk. The reason to make these specifications for robustness levels is similar to findings of Balkan (2010), since we realize that the model outputs are close or equal to the highest bid prices with lower probability of win values, nearly equal to zero, no matter what the project characteristics are for the values of γ higher than 0.4. Increasing the robustness level to more than 0.4 leads to an enormous increase in the proposed bid price which is not applicable in real life. Hence, we decide to utilize three different levels for the robustness parameter as $\gamma=0$ representing risk-seeking decision behavior, $\gamma=0.2$ representing mildly risk-neutral decision behavior and $\gamma=0.4$ representing risk-averse decision behavior. With these specifications, we can get a better understanding of the model by conducting more consistent analyses. Also, the model itself proposes conservative solutions due to the use of risk-oriented scenarios and EVA methodology which considers the cost of capital in any case, even if totally risk-seeking approach is utilized. Above all, employing the same level of robustness with the study of Balkan (2010) gives us a chance to make more healthy comparisons by using the same parameter levels.

Choosing the specified robustness levels is also practical for the current situation of the company, because the managers do not even bother to offer a bid price, if risk-averse approach is much more dominant by making γ close to 1. However, the company itself is free to choose the most appropriate level for γ, as regards to several criteria such as the company's current capacity, the availability of this capacity and the management's approach towards to risk functions. Therefore, the conditions in which the company describes itself define the preferred risk function for the company. For example, if the company is in a fragile economic condition and cannot risk paying any penalty cost, γ may be set higher by the company to avoid financial risks that results in higher bid prices.

Model scenarios may be generated instead of using robust parameters by employing worst-case assumptions in such a way that the probability of a financial loss is diminished as much as possible. However, worst-case scenarios would give us more conservative outputs by decreasing the probability of winning, and in this case the company does not prefer to proceed. To obtain a trade-off between probability of winning and financial gain, the use of robustness parameters is a better choice (Balkan, 2010).

Results of the base case projects

Project CP:

In this part, the outputs of the robust optimization model are examined for project CP to see the impact of the robustness term on solutions. As it is seen from Table 13, the company financially suffers with a probability of 22% for 3 out of all problem instances. With a pure risk-seeking perspective, where $\gamma=0$, the probability of a financial loss is positive for 21 problem instances. The desired rate of EVA, which is 15%, is not possible to accomplish for also these 21 instances of risk-seeking solution set. However, in the risk-seeking solution set, the rate of return values also fall certainly below the desired level, that is 15%, for 12 problem instances.

For risk-neutral and risk-averse solution sets, probability of a financial loss decreases considerably compared to risk-seeking solution set. The problem instances have lower probabilities of a financial loss as being either nearly close to zero or equal to zero. In both solution sets, financial loss occurs with a probability which is less than 2% for all problem instances. The desired rate of EVA can be achieved for 15 problem instances of R1 set, and 21 problem instances of R2 set. By looking at the desired level of ROR, this desired level can be exceeded with a probability of more than 3% in all problem instances for R1 set and with a probability of more than 9% in all problem instances for R2 set. Then robustness solution sets always have positive probability values for being above the desired ROR, whereas only 36 instances of 72 robustness solution instances have positive probability values for being above the desired ROEVA (Table 13). Also, the rate of EVA values tend to be lower than ROR values for the same bid price, since EVA also consider the cost of capital.

By considering all problem instances of project CP, we realize that the probability of winning the bid decreases while trying to reduce the probability of suffering from a financial loss with an increase in the probability of being above the desired rate of EVA. For the risk-seeking solution set, offered bid price win the competition with an average probability of 79%. However, the probability of a financial loss reduces from 22% to 0.6% in the "Robustness" solution set of R2, while the probability of winning falls down with a little decrease from 79% to 69% (Table 13).

To make a comparison with the former research, our model produces better results for robustness solution sets, because there is a lower decrease in the probability of winning, and financial loss probabilities are much closer to zero while going from risk-seeking solution set towards risk-averse solution set (Tables 13, 14 and 15). We also see that maximum probability of suffering from a financial loss is less in all our solution sets. Nevertheless, the existence of higher market utility attribute in project CP prevents from huge bid price differences between our study and Balkan (2010).

Since the market share impact has an important effect on the bid price selection decision, this project demands for higher probability of win values when compared to the other projects due to high level of market share effect. Therefore, the offered bid prices are much closer to the minimum level of acceptable bid price especially for the risk-seeking case.

Table 13 Project CP Solution Details for the Proposed Model

BID PRICE (million $)	Solution Set # of problem instances, Exp	 # of problem instances, R1	 # of problem instances, R2	Prob. of (ROEVA<15%)	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
61	3			100%	100%	22%
62	3			100%	100%	14%
63	3			100%	100%	8%
64	3			100%	100%	3%
65	3	12		100%	97%	1.6%
66	6	9	15	100%	91%	0.6%
67	6	6	9	95%	82%	0%
68	6	3	3	89%	63%	0%
69	3	6	9	79%	41%	0%

Table 14 Project CP Solution Details for the Previous Study (Balkan, 2010)

BID PRICE (million $)	Solution Set # of problem instances, Exp	 # of problem instances, R1	 # of problem instances, R2	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
60	6			100%	38%
61	3			100%	22%
62	6			100%	14%
63	9			100%	7%
64	3	3		100%	2%
65	3	6	3	97%	1%
66	4	9	9	91%	0.4%
67	2	12	15	80%	0%
68		6	9	60%	0%

Table 15 is the summary of the robustness effect on Project CP solutions.

Table 15 Project CP Analysis

Project	Average pow			# of problem instances with more than 2% prob. of suffering from a financial loss			Maximum prob. of suffering from a financial loss		
	Exp	R1	R2	Exp	R1	R2	Exp	R1	R2
CP (proposed model)	79%	73%	69%	12	0	0	22%	1.6%	0.6%
CP (Balkan, 2010)	86%	78%	73%	27	3	0	38%	2%	1%

In the context of probability of winning, both R1 and R2 in addition to risk-neutral choice can be preferred for project CP to reflect the risk effect, because they all have probability of win values around 70%. Yet, any one of R1 and R2 sets should be employed to avoid from financial loss as much as possible.

Project PM:

This project offers only one utility attribute among all which is the rate of EVA. Therefore, our model tries to produce more conservative results due to lack of any other utility attribute. Hence, relative offered bid prices compared to minimum level of acceptable bid price and consequently the rate of return values are much higher than the values of other projects (Table 16).

Risk-seeking solution set for project PM yields a quite low level of maximum probability of financial loss which is 1.8%, and this financial loss only occurs due to the unexpected exchange rate scenario. Besides, all instances of this solution set have positive probability of achieving the desired rate of EVA and a probability of more than 66% for being above the desired ROR level, because the model attempts for maximizing the financial gain as much as possible due to the absence of any other utility attribute for the project other than the rate of EVA.

In the "Robustness" solution sets of negative portion of EVA for both γ=0.2 and γ=0.4, the results of the model indicate lower average probabilities of financial loss. Both sets result in a probability of a financial loss of 0 for all problem instances. This conclusion is reasonable, since the only term affecting the objective function is the rate of EVA in this project, and this rate is affected by the risk level of robustness solution set. Hence, the model tries to minimize the risk effect as much as possible for "Robustness" solution sets by maximizing EVA and minimizing possible financial loss.

Our model offers more conservative results for project PM compared to the results of Balkan (2010) in Table 17, because we also consider logistics risks, technical risks and the cost of company's capital within the model even in the risk-seeking case where $\gamma=0$. The existence of only one utility attribute gives us the chance to see how much better our model is in terms of risk consideration. We can best observe the conservative behavior of our model for project PM in minimum offered bid price value for risk-seeking solution set which is 89 M $, and this value is much higher than the value of previous research (Balkan, 2010) which is 84 M $.

Table 16 Project PM Solution Details for the Proposed Model

BID PRICE (million $)	Solution Set			Prob. of (ROEVA<15%)	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
	# of problem instances, Exp	# of problem instances, R1	# of problem instances, R2			
89	3			60%	34%	1.8%
90	3			45%	19%	0.2%
91	6	3		45%	19%	0%
92	9	6	3	42%	19%	0%
93	6	9	6	42%	19%	0%
94	9	6	9	42%	19%	0%
95		6	6	34%	11%	0%
96		6	6	30%	11%	0%
97			6	30%	3%	0%

Also, we realize that average probability of winning values for all robustness types are lower in our study for the project PM compared to previous research as a result of higher offered bid prices in our model outputs (Table 18).

Table 17 Project PM Solution Details for the Previous Study (Balkan, 2010)

BID PRICE (million $)	Solution Set: # of problem instances, Exp	Solution Set: # of problem instances, R1	Solution Set: # of problem instances, R2	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
84	3			58%	2%
85	3	3		58%	2%
86	6	3		44%	2%
87	9	6	6	30%	2%
88	6	5	3	30%	2%
89	3	7	6	30%	2%
90	6	6	9	16%	0%
91		3	6	16%	0%
92		3	3	16%	0%
93			3	16%	0%

Table 18 Project PM Analysis

Project	Average pow			# of problem instances with more than 2% prob. of suffering from a financial loss			Maximum prob. of suffering from a financial loss		
	Exp	R1	R2	Exp	R1	R2	Exp	R1	R2
PM (proposed model)	51%	44%	39%	0	0	0	1.8%	0%	0%
PM (Balkan, 2010)	63%	56%	48%	0	0	0	2%	2%	2%

'Risk-seeking' solution set is logical to employ for this project with average probability of winning of 51%, because the probabilities of financial loss are close to each other for all solution sets of robustness levels and the average probability of winning value for the 'Expected' solution set is much preferable comparing to other robustness level values (Table 18). Since we employ EVA methodology, our model would already provide relatively preventive results for even risk-seeking solution set of project PM.

Project GJ:

As for the project characteristics, this project is also an R&D type as the project CP, but it is not really straightforward for the company. Therefore, the probability of success is lower as being equal to 80%. As a result, the least probability of success among three projects is for this project. However, a small amount of government funding is available due to national benefits it provides for the defense industry of the country. Market share impact coming with this project is positive, but smaller than the project CP's. Then, the most distinguishing feature of this project is the existence of market share impact and government funding, even if they are in minor amounts.

Financial loss probabilities in risk-seeking solution set are positive for the 24 problem instances, but not more than with a probability of 3%. 33 instances of all problem instances in this set have probability values higher than zero for being above the desired rate of return level which is quite high for the risk-seeking solution set. However, 6 instances of this solution are definitely below the desired rate of EVA (Table 19).

In the "Robustness" solution sets for both $\gamma=0.2$ and $\gamma=0.4$, the results of the model indicate lower levels for maximum probability of suffering from a financial loss compared to risk-seeking solution set. For R1 solution set, the model almost eliminates the probability of a financial loss totally. The same is also valid for the outputs of R2 solution set. Consequently, it is clearly seen that the probability of the occurrence of a financial loss decreases when the attitude of the management shifts towards to risk-aversion.

If the outputs are evaluated in terms of the desired level for the rate of EVA, all instances have a positive probability for being above this level in R1 and R2 sets. Nevertheless, most of the problem instances in risk-seeking solution set have a positive percentage of being more than this desired level. This percentage increases while the robustness term increases as it seems. Therefore, these conclusions imply that EVA is a much more conservative financial measure than ROR.

From the outputs of project GJ, it is seen that the model offers higher proportions for bid prices compared to the expected project cost. The reason is that the other utility attributes, the market share and the government funding, do not create a major difference for the utility function of the objective function because of the small market share impact and limited government funding availability. Therefore, the model offers relatively higher ROEVA rates compared to the rates of project CP to compensate for the effect of other utility attributes in low rates. Due to the higher offered bid price values, probability of suffering from a financial loss and probability of winning values are obviously lower (Table 19).

As it is stated, project GJ has a positive market share effect and government funding, even if their amounts are not much, which is not the case for project PM. Thence, project GJ has lower probabilities for catching the desired level of ROEVA, because the model tries to maximize the utility level of these attributes by lowering the offered bid price rate compared to the cost of the project. On the other hand, project GJ offers higher bid prices relative to the expected cost compared to project CP, although project GJ has positive values in all predetermined utility attributes, and project CP has only one positive predetermined utility attribute. The reason is that the utility level of market share is really high for project CP as being equal to 4 out of 5, and the model offers much lower bid prices relative to project cost to increase the effect of this utility in the objective function.

If an analysis is carried out to see the differences for project GJ between the results of Balkan (2010) in Table 20 and those of our model, we observe that probability of financial loss is lower for our model for all sets, while the probability of being above the desired ROR level is lower for Balkan (2010). This result complies with what we try to accomplish in the model by inserting additional risk factors.

When we evaluate the average probability of winning values, it is seen that our results for project GJ are lower compared to the previous research results. Robustness parameter, γ, for R1 reduces the probability of suffering from a financial loss from 3% to 0.4% with a relatively minor decrease in the probability of win around 6% (Table 21).

Table 19 Project GJ Solution Details for the Proposed Model

BID PRICE (million $)	Solution Set # of problem instances, Exp	# of problem instances, R1	# of problem instances, R2	Prob. of (ROEVA<15%)	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
132	3			100%	100%	3%
134	3			100%	90%	1%
136	6	6		98%	77%	0.4%
137	6	9	3	84%	65%	0.4%
138	6	3	6	77%	53%	0.2%
139	6	6	6	71%	50%	0%
140	3	6	9	65%	38%	0%
141	3	3	3	58%	28%	0%
142		3	3	53%	19%	0%
143			6	53%	11%	0%

Table 20 Project GJ Solution Details for the Previous Study (Balkan, 2010)

BID PRICE (million $)	Solution Set # of problem instances, Exp	# of problem instances, R1	# of problem instances, R2	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
129	1			100%	10%
130	2			100%	8%
131	3			100%	5%
132		6		100%	2%
133	3	3	3	92%	1%
135	6	3	2	86%	0.2%
136	6	8	6	76%	0.2%
137	3	2	6	62%	0.2%
138	3	4	5	48%	0%
139	6	7	6	46%	0%
140	3	2	5	36%	0%
141		1	3	26%	0%

In the ‘risk-seeking’ solution set, the company has the probability of winning the bid in 65% of the time. The probability of a financial loss is decreased from 3% to 0.4%, whereas the probability of win is decreased from 65% to 54% in the “Robustness” solution sets for R2 (Table 21). The decrease rate for the probability of financial loss is higher in our model compared to the earlier research as it is seen from Table 21, meaning that our model can lower financial loss probabilities for robustness sets with a relatively less decrease in probability of winning.

Table 21 Project GJ Analysis

Project	**Average pow**			**# of problem instances with more than 2% prob. of suffering from a financial loss**			**Maximum prob. of suffering from a financial loss**		
	Exp	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**
GJ (proposed model)	65%	59%	54%	6	0	0	3%	0.4%	0.4%
GJ (Balkan, 2010)	74%	68%	63%	6	6	0	10%	2%	1%

Then the most appropriate risk level to employ is γ=0.2 for project GJ, since the probability for a financial loss is almost equal to 0, and the average probability of winning the bid is close to 60%.

<u>An alternative solution approach for project GJ:</u>

As it is mentioned above, the model for original version of project GJ with a bid quantity of 8 units cannot be solved because of the time limitations of the solver. After making several runs, we realize that the solver cannot solve the model for the bid price intervals bigger than 40. Then we change the data for project GJ by reducing the delivery size from 8 units to 3 units and make the analysis for the modified version of project GJ above.

However, this limitation is a constraint for our model which means a drawback needed to be eliminated. Hence, we develop a method that starts with the decomposition of the available bid price interval into subintervals, while the highest bid price remains the same. After executing the model for the first subinterval for all run types, we decide to execute it again for the next interval segment and for certain run types depending on the outputs. To choose the run types to be executed with the next bid price subinterval, we need to be aware that the model will choose the optimum bid price for any run, if that bid price value is in the available bid subinterval, otherwise it will choose the closest value. Then we execute the model for the next bid price subinterval only for the run types that give the maximum available bid price in the current subinterval.

To reach the logic behind this alternative method, we consider that the main factor affecting the selected bid price is the probability of winning with the impact of it on the multi-attribute utility function in the objective function. The rate of EVA attribute tries to increase the offered bid price, whereas the other two predefined utility attributes, market share and government funding, try to minimize it in order to increase probability of winning. Also, our probability of winning function is a decreasing concave function of bid price, that is, the probability of winning pushes the model towards the maximum bid price possible. Hence, the model would always offer the closest bid price to the optimum value, if the optimum bid price value is not in the available bid price subinterval. Otherwise, it would always give the optimal one. In addition, all labor and financial decision variables other than the bid price selection decision variable are determined according to the selected bid price in such a way that the rate of EVA utility is maximized. Then we can conclude that it is possible to divide the offered bid price interval by keeping the highest possible bid price fixed, so the probability of winning value of each available bid price value will be the same, as if we use the whole interval between the lowest and the highest bid price values.

With this specified approach, we can analyze the original version of project GJ with a delivery size of 8 units. We have a bid price interval of 78 in this version with a highest bid price value of 320 M $ and lowest bid price value of 242 M $. We can divide the possible price interval into two as between 242 M $ - $280 M and 280 M $-320 M $. After executing all 108 run types for the first interval, we divide the outputs into two as: lower than 280 M $ and equal to 280 M $. We do not proceed any further for the runs producing lower bid price values than 280 M $. For the runs offering the bid price value of 280 M $, we execute the model again for the second bid price subinterval between 280 M $ and 320 M $, and we find the offered bid price values for this subinterval. Hence, we can finalize the outputs for each run after completing two consecutive executions of the model.

First execution:

We see that 6 instances of the risk-seeking solution set, 9 instances of the risk-neutral solution set and 12 instances of risk-averse solution set give the maximum bid price value available in the given subinterval. Therefore, we execute the model once again for only these instances. The results are in Table 22.

Second execution:

All results of the second execution are higher than 280 M $ as expected. Then, we can reach the results by eliminating the results in the first execution which give the bid price value of 280 M $ and combining the remaining outputs with the results of the second execution (Table 23).

The combination of outputs for the first and second execution is in Table 24.

For 99 out of 108 problem instances, financial loss probability is smaller than 1%. The "Robustness" solution sets have lower maximum probability of suffering from a financial loss compared to risk-seeking solution set. This result is consistent with both the modified version of project GJ and other two projects.

If the outputs are evaluated in terms of the desired level of ROEVA, 12 instances in "Expected" solution set are certainly under this level, whereas all problem instances the "Robustness" solution sets have a positive percentage of being more than this desired level. For the desired rate of ROR, all instances in "Expected" solution set is above this rate with a positive probability, while also all problem instances the "Robustness" solution sets have a positive percentage of being more than the desired ROR level.

Table 22 Project GJ – Alternative Approach Solution Details for the Proposed Model Execution 1

BID PRICE (million $)	Solution Set: # of problem instances, Exp	# of problem instances, R1	# of problem instances, R2	Prob. of (ROEVA<15%)	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
265	3			100%	96%	2%
267	3			100%	92%	1.2%
269	3			100%	89%	1.2%
270	3			100%	86%	0.6%
271	3			98%	82%	0.6%
272	3	6		92%	72%	0.6%
274	3	3		81%	59%	0%
275		3		72%	50%	0%
276		3	3	72%	50%	0%
277	3	3	9	67%	50%	0%
278		3	6	63%	46%	0%
279	6	6	6	59%	36%	0%
280	6	9	12	59%	36%	0%

Table 23 Project GJ – Alternative Approach Solution Details for the Proposed Model Execution 2

BID PRICE (million $)	Solution Set: # of problem instances, Exp	# of problem instances, R1	# of problem instances, R2	Prob. of (ROEVA<15%)	Prob. of (ROR<15%)	Prob. of suffering from a financial loss
282	3			36%	23%	0%
284		3	3	36%	23%	0%
285	3			36%	23%	0%
287		3	3	33%	19%	0%
288		3	3	33%	19%	0%
289			3	28%	19%	0%

The comparison of the original project GJ with other projects is also quite similar with the comparison of the modified version. This project offers relatively lower bid prices compared to project PM; on the other hand, it gives higher bid prices relative to project CP. The original and modified version results are very close to each other with minor differences due to the differences of the delivery size and the available bid price interval. Also, once more, we reach the conclusion that our results for the original project GJ are much more protective in terms of probability of financial loss compared to the earlier study of Balkan (2010) in Table 25.

Table 24 Project GJ – Alternative Approach Solution Details for the Proposed Model (Combined)

BID PRICE (million $)	Solution Set: # of problem instances, Exp	# of problem instances, R1	# of problem instances, R2	Prob. (ROEVA<15%)	Prob. (ROR<15%)	Prob. of suffering from a financial loss
265	3			100%	96%	2%
267	3			100%	92%	1.2%
269	3			100%	89%	1.2%
270	3			100%	86%	0.6%
271	3			98%	82%	0.6%
272	3	6		92%	72%	0.6%
274	3	3		81%	59%	0%
275		3		72%	50%	0%
276		3	3	72%	50%	0%
277	3	3	9	67%	50%	0%
278		3	6	63%	46%	0%
279	6	6	6	59%	36%	0%
282	3			36%	23%	0%
284		3	3	36%	23%	0%
285	3			36%	23%	0%
287		3	3	33%	19%	0%
288		3	3	33%	19%	0%
289			3	28%	19%	0%

Average probability of winning results are also similar with the previous analysis of project GJ with the delivery size of 3 units. Robustness parameter, γ, for R1 decreases the probability of suffering from a financial loss from 2% to 0.6% with a relatively minor decrease in the probability of win around 7%. The previous study gives higher average probability of winning values due to preventive risk management attitude of our model (Table 26).

It is logical to employ the risk level γ=0.2 for project GJ, because the probability for a financial loss is almost zero and the average probability of winning the bid is around 59%. However, maximum probability of suffering from a financial loss is not really higher for this project, so risk-seeking solution set can also be used by the decision-makers to maximize the probability of winning.

Table 25 Project GJ – Alternative Approach Solution Details for the Previous Study

BID PRICE (million $)	Solution Set			Prob. (ROR<15%)	Prob. of suffering financial loss
	# of problem instances, Exp	# of problem instances, R1	# of problem instances, R2		
259	3			100%	7%
262	3			100%	3%
266	3	2		93%	1%
267		3		91%	1%
269	3	4		87%	1%
270	3	3	2	85%	0.4%
271		3	4	80%	0.4%
272	6	5	2	71%	0.4%
273		1	5	66%	0.4%
274	3	1	3	57%	0%
275		2	3	48%	0%
276	3	2	3	48%	0%
277	3	1	4	48%	0%
278	3	6	3	44%	0%
279			3	36%	0%
281	3	3	2	29%	0%
282			2	23%	0%

Table 26 Project GJ – Alternative Approach Analysis for the Proposed Model

Project	Average pow			# of problem instances with more than 2% prob. of suffering from a financial loss			Maximum prob. of suffering from a financial loss		
	Exp	R1	R2	Exp	R1	R2	Exp	R1	R2
GJ (proposed model)	65%	59%	52%	3	0	0	2%	0.6%	0%
GJ (Balkan, 2010)	74%	67%	62%	9	0	0	7%	1%	0.4%

<u>Validation of alternative approach with project CP:</u>

To validate our alternative approach, we decompose the bid interval of project CP into two subintervals as 60 M \$ to 70 M \$ and 70 M \$ to 80 M \$. After the decomposition of the available interval, we execute the model for the first subinterval. When the outputs of the first execution are evaluated, it is seen that the model gives the same results with the original version of project CP, since the original version offers bid prices smaller than 70 M \$.

After the second execution of all problem instances with the second subinterval, it is seen that all run types in all solution sets give 70 M \$ as the offered bid price which is the closest value in the available bid price interval. Hence, our alternative approach is also supported by the results of project CP.

<u>General conclusions for the model:</u>

We conclude that average probability of winning value in our study is smaller than the previous study for each project, since more risk factors are included in our model and the offered bid prices increase to compensate for these risk factors even in the 'risk-seeking' solution set, when γ is equal to 0. It is seen from the outputs that our model provides more conservative solutions for all projects even in the case of no risk factor consideration. However, EVA itself includes the cost of capital independent from risk conditions and that makes our model as much realistic as possible by decreasing the average probability of winning for each robustness level as a trade-off.

These findings are in comply with our expectations from the model, since we aim to reflect the reality of the company much better in terms of risk consideration by integrating work-force decisions in and using ROEVA instead of ROR by making the model much more realistic and protective even for the risk-seeking problem environment.

As a comparison with the study of Balkan (2010), we get a much more protective decision-support tool for bid pricing process with the use of EVA instead of ROR as the financial measurement tool. Also, the involvement of workforce decisions into the model and the increase in the risk level consideration by involving logistics risk are the other factors which make our proposed approach more conservative. The model responses to these changes with the increase in the offered bid prices relative to the solutions of Balkan (2010).

Parameter behaviors

<u>Probability of Success</u>

Probability of success term is project specific and assumed to be determined independently from any element in the model. This term is an input to the objective function and a constant multiplier. It is multiplied with the output of the multi-attribute function in the objective.

Although there are three different run types of probability of success, we realize that the offered bid prices for each of these run type is same, if the attributes other than the probability of success are the same.

Hence, we conclude that even if probability of success term affects the value of the objective function, it does not have a role in determining the optimum bid price. However, this term affects the value of the objective function after the optimum bid price has been already decided by the model.

Our modeling approach and the related assumptions presume that the model considers only one individual project at a time, and parameters including the probability of success are defined accordingly. Since probability of success term does not have an effect on defining the optimum bid price, we exclude to examine the effect of this parameter on the model behavior.

Probability of Winning

Probability of winning factor is determined by several factors as the offered bid price, markup, exterior factors, etc. Due to their effects on probability of winning, exterior factors known as environmental conditions become highly significant for the company. These factors over which the company has no control could even result in giving up the bidding process of a project. Then, environmental conditions through which bidding process is executed are really important when identifying the optimum value for a bid price to refrain from financial lost. Hence, the attributes defining the problem environment are needed to be considered in our model.

As an illustration for the effect of exterior elements to the bidding process of the company, if the company has strong relationships with potential customers, this increases the reference factor of the company for the project and creates a competitive advantage for the company against her competitors. By using this advantage, the company can decide to offer relatively higher bid prices, however, the offered bid price can turn out to be lower in an environment including several rivals.

To make a comparison among projects in terms of the probability of winning factor, it is deducted from the model outputs that lower market share impact pushes the model to offer relatively higher bid prices by decreasing probability of winning. The model for project CP offers around 80% probability of winning in a high probability of winning environment; and 68% probability of winning in a low probability of winning environment (Table 27). However, project GJ has a relatively lower market share utility attribute compared to project CP, although it has minor government funding utility. Since these two utility attributes are more penurious for project GJ, the model places higher bid prices relative to the expected cost to maximize objective function by renouncing the probability of winning (Table 27). Project PM has a lower probability of winning compared to the others due to the effect of the absence of the market share impact and the government funding, and probability of winning is only around 52% in high probability of winning environments, which could be accepted convenient for project PM.

It is clearly seen that projects CP and GJ are relatively more resilient to changes in the problem environment with the effect of utility attributes other than the rate of EVA which are fixed and project-specific.

In comparison with the previous study regarding probability of winning, we realize that average probabilities of winning for both high and low probability of winning environments are lower in our findings for all projects, which is a result in compliance with what we expect from the model, since we increase consideration of risk level by employing both logistics and labor risks in addition to EVA methodology. Nevertheless, this higher emphasis on risks results in a reduction in probability of winning.

With regard to robustness terms, it is seen that the robustness sets constitute a major difference in probability of winning, which is compatible with the decrease in average probabilities robustness sets.

Table 27 'Probability of Win' Intervals for Different Environmental Conditions

Project	**Environment**	**Exp**	**R1**	**R2**
		Probability of winning the bid interval		
CP	High pow	82-84%	79-81 %	76-78%
	Low pow	73-77%	66-68%	60-64%
GJ	High pow	70-72%	65-67%	57-61%
	Low pow	57-63%	52-54%	48-52%
PM	High pow	57-61%	49-55%	43-47%
	Low pow	41-44%	35-39%	28-38%

6.2.2. Sensitivity Analyses on Scenario Probabilities

The probability of unexpected exchange rate scenario is equal to 2% for ordinary case as in above analyses, since high probability for this scenario is not logical to employ under normal circumstances. However, this may not always be the case, since it is possible that an unexpected crisis situation in the scope of exchange rate scenario can emerge. Therefore, we study the effect of unexpected exchange rate scenarios on the proposed model in this section.

We conduct sensitivity analyses by implementing our model with different scenario probabilities through making changes in the probability of 'unexpected exchange rate' scenario and relative changes in the other scenario probabilities. Hence, we can see how sensitive our model is to the changes in scenario probabilities.

We increase the probability of the crisis scenario from 2% firstly to 16% and then to 30% for each project. For project CP, these changes lead to a relatively small increase in the expected cost of the project. We see that "Expected" solution set results as well as the average of probability of winning are affected in minor amounts by these minor cost increases. On the other hand, it is clear that "Robustness" solution sets have a distinguishable effect on the probability of suffering from a financial loss in the crisis scenarios by making the model generate more conservative results (Table 28).

For project PM, the change in the expected cost of the project is relatively higher due to the great portion of national currency costs in the project. However, the increase in minimum and maximum bid prices for "Expected" solution set does not change much considering the changes in the expected costs. Also, robust solution sets provide a distinguishable decrease in probability of suffering from a financial loss for crisis scenarios. Nonetheless, probability of financial loss reduces with the effect of robustness set, when the probability of 'unexpected exchange rate scenario' increases (Table 29).

The increase in the probability of crisis scenarios results in a slight amount of increase in the expected cost of the project for project GJ. In parallel, minimum and maximum level of offered bid prices for “Expected” solution sets do not change in considerable amounts. Once again, robust solution sets provide a huge decrease in probability of suffering from a financial loss for crisis scenarios (Table 30).

If we evaluate risk behavior of the model by considering ‘unexpected exchange rate’ scenario, we see that the increase in the probability for crisis scenarios tends to increase both maximum and minimum bid price values. Also, robust scenario sets are more responsive to changes in the probability of ‘unexpected exchange rate’ scenario compared to risk seeking solution set. Therefore, “Robustness” solution sets provide a more preventive set of outputs to diminish the effect of increasing probability of unexpected financial circumstances.

Table 28 Summary Table for Project CP under Different Extreme Scenario Probabilities

Probability of extreme scenarios	Expected Cost(M $)	Minimum Bid Price (M $)			Maximum Bid Price (M $)			Average pow			# of problem instances with prob. of suffering from a financial loss			Maximum prob. of suffering from a financial loss		
		Exp	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**
Unexpected USD rate =2%	60	61	65	66	69	69	69	79%	73%	69%	21	21	15	22%	2%	0.6%
Unexpected USD rate =16%	61	61	66	67	69	70	70	80%	72%	68%	21	9	0	38%	7%	0%
Unexpected USD rate =30%	61.5	62	67	68	69	70	72	80%	71%	66%	21	0	0	48%	14%	0%

Table 29 Summary Table for Project PM under Different Extreme Scenario Probabilities

Probability of extreme scenarios	Expected Cost(M $)	Minimum Bid Price (M $)			Maximum Bid Price (M $)			Average pow			# of problem instances with prob. of suffering from a financial loss			Maximum prob. of suffering from a financial loss		
		Exp	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**
Unexpected USD rate =2%	75	89	91	92	94	96	97	51%	44%	39%	6	0	0	2%	0%	0%
Unexpected USD rate =16%	77.5	89	92	94	95	97	98	49%	41%	32%	3	0	0	16%	9%	2%
Unexpected USD rate =30%	79.5	90	94	96	95	98	100	48%	36%	29%	3	0	0	35%	22%	0%

Table 30 Summary Table for Project GJ (size=3 units) under Different Extreme Scenario Probabilities

Probability of extreme scenarios	**Expected Cost(M $)**	**Minimum Bid Price (M $)**			**Maximum Bid Price (M $)**			**Average pow**			**# of problem instances with prob. of suffering from a financial loss**			**Maximum prob. of suffering from a financial loss**		
		Exp	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**	**Exp**	**R1**	**R2**
Unexpected USD rate =2%	120	132	136	137	141	142	143	65%	59%	54%	24	18	9	3%	0.4%	0.4%
Unexpected USD rate =16%	122	133	138	139	141	142	145	65%	55%	45%	21	18	15	11%	8%	0.4%
Unexpected USD rate =30%	124	135	140	145	142	143	147	64%	52%	41%	21	12	0	20%	5%	0%

6.2.3. Computational Times

Our model is implemented for three different projects, and optimal solutions are found on a computer with a 2.00 GHz processor, and 2.96 GB RAM. The maximum average computational time for a project which is around 2600 seconds belongs to project GJ, since this project has the maximum available bid price interval among all others.

Computational times are really acceptable considering the lifecycle duration of projects which is 5 years on the average. Also, the bid price determination process of the company lasts for months, even all required data used in the model are readily available. Hence, the computational times for our model are reasonable while considering both the importance and requirements of the bid price determination process.

As a final remark for the computational times, it is possible to reach the results of the model more quickly by implementing the alternative decomposition method which we used in the execution of the original version of project GJ. The available bid price interval can be divided into subintervals, and the model can be run on multiple computers for each bid price subinterval in order to shorten the total computation time of the model.

CHAPTER 7

CONCLUSIONS AND FURTHER RESEARCH ISSUES

7.1. Concluding Remarks

We proposed a value-based risk management approach with robust optimization for the bid pricing problem considering the projects with long project lifecycle, which is consistent with the environment of the company under consideration. Our model takes into account the priorities of the management for certain project attributes as the market share effect, the rate of EVA to project financial cost and the government funding. In the model, technical risk preference of the management is reflected by employing a technical risk function. By the different probability-of-win functions, we consider several factors in defining the bid competition environment as realistic as possible. Financial and supply chain uncertainties are attempted to be annihilated with the use of the robust optimization methodology.

The model is executed for several times with the predefined preference functions under specified environmental conditions with three different robustness levels so as to be able to observe the output behavior under different conditions. Consequently, it turns out that robust solutions are more responsive to uncertainties as expected when the outputs are examined for different robustness levels.

Although the size of the available bid price interval to be evaluated by the model turns out to be a limitation from the computational standpoint, we propose an alternative decomposition method that divides the bid price interval into subintervals and deals with these discrete subintervals individually to overcome this drawback. Therefore, our model is able to solve any problem of any bid price interval size with this alternative method.

Hence, our solution approach proposes a flexible and integrated method for dealing with the changes in the problem environment, project characteristics or the attitude of the management towards to project attributes. Also, the change in the preferences of the management can be easily reflected in the model by including the related utility functions. Therefore, the model can surely be used as a decision support tool which highly resilient to ambiguities in the problem environment.

7.2. Further Research Issues

In the literature section, several studies are available about project selection methodologies most of which are about R&D projects and pricing techniques. However, elimination of risk sources along the bidding process has only been considered only once by Balkan (2010). Nevertheless, no such work exists in the scope of logistics risks.

Therefore, our study tries to address this deficiency in the literature by solving the bid pricing problem through the elimination of financial, technical and logistics risks, and to find the optimum bid price for one project at a time. Furthermore, even though the model currently does not allow considering more than one project at a time, it may still be used to compare several projects at a time by their objective function values to create a project portfolio selection methodology with only small alterations in the approach. With a further study then, the comparison among multiple projects can be addressed by employing the methodology in this thesis.

Also, our model mainly aims to mitigate the negative effects of uncertainties. By considering financial, technical and logistics uncertainties, the model defines the total utility of a project so as to identify how eager the company is about the bid project. Then, other possible utility attributes specific to the problem environment can be reflected to our approach.

The projects of the company always require for the participation of the related army forces and governmental people for the delivery activities. In addition, there exist several points for which the company expects and waits for the answer of external approval authorities. Even though these delays cannot result in penalty costs for the company, the payments can be delayed, and so the money loses its value due to inflation. In addition, the customers can demand for additional requirements throughout the project lifecycle, so the supply chain and technical risks can be more severe because of these additional requirements. Apart from external factors, indirect costs not included in the model may affect the profitability of a project. These non-project related factors may also be integrated into our model to achieve a much more dynamic and realistic decision-support tool in bid pricing.

The risks under consideration in our model are introduced with a holistic approach, i.e., risk factors are valid for all types of labor and material. However, reality can be much more different. The risk level for a material or a labor type can be different from the others. A certain material can have a high level of risk due to the structure of the type or international supplier profile. Also, some labor types may be require performing some more risky tasks as in chemicals, and hence may include higher risk levels. Therefore, future studies may assign different risk levels for each type of labor and material to better comply with the actualities of the work environment of the company.

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