UNIVERSITY OF CALGARY

Assessing Final Cost of Construction at Bid Time in Oil and Gas Engineering Construction

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Assessing Final Cost of Construction at Bid Time in Oil and Gas Engineering Construction" submitted by Ganyo Nutakor in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Literature indicates that there is usually a difference between bid price (or estimate based on unit rates) and final cost at the end of a construction project especially with the low bid procurement system. As a result, a study was conducted, which identified and quantified the factors that account for the difference between bid price and final cost of construction under different project conditions for stipulated price, unit price and cost plus contracts. The cumulative density function curve resulting from simulating the cost impact data shows potential cost overruns (the amount by which actual cost exceeds estimated cost) that might be expected in the delivery of Oil and Gas engineering construction projects in Alberta, Canada.

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DEDICATION

This thesis is dedicated to

My dear wife, Helena who has always been very supportive

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CHAPTER ONE INTRODUCTION AND SUMMARY

This introductory chapter provides a general overview of this research. It provides a brief background by way of introducing this work. Presented in this chapter are: the performance of the Canadian construction industry with special reference to the province of Alberta; a literature review identifying the gaps in existing knowledge; principal findings and recommendations of this study. Detailed work undertaken in completing this thesis is found in subsequent chapters.

1.1 BACKGROUND

Buying construction contract services usually involves a process. Most companies and government agencies have policies that require competitive bids for contract work unless special circumstances dictate that a sole source contract is required by directly negotiating with a selected contractor (Huston 1996; Marsh 2000; Betty 1993). One of the most important, but difficult, procedures in a construction procurement process is contractor selection. This is a major issue to be dealt with following the decision by an owner to procure construction services for a proposed project.

One of the most common methods used to award construction contracts is the lowest bidder system (Hung 2002; Assaf et al. 1998; National Research Council 1994). It is a competitive system and most contractors obtain their work through it; price being a predominant factor (Silberman 1993; Clough 1981) or the sole criterion (Park 1979). This price-based procurement system has received some criticism over the years because it does not ensure that the client gets an optimum tender in terms of final cost, time and quality. While the awarding of contracts for construction work on the basis of competitive bids offers certain advantages to both owners and contractors, many of the construction industry's problems can be attributed directly to the practice of making price the sole criterion (Park 1979). If bid price becomes the focal point, the owner will usually end up accepting a low-price bid from a contractor who is not best suited to carry it out. While the initial price may be low, the question arises as to whether the contractor will complete the work at the lowest final cost to the owner? In this context, Hartman, (2000) stated that the lowest bid is attractive, but is often not necessarily the lowest final cost. In administering such contracts, there is the likelihood of aggressive and unjustified claims by contractors due to the submission of "cut-prices". This may result in disputes, which could be very costly to both parties to the contract. There is also the possibility of increased contract administration costs to the owner if the contractor must perform to set standards and specifications without cutting corners. In short, the result though difficult to quantify, may be lower quality work that will cost more in maintenance and early replacement where necessary.

On the part of owners for example, a study conducted by Semple et al. (1994) on 24 projects in western Canada involving 19 private and 5 public sector projects revealed that time and cost overruns were extremely significant on lump sum, unit rate or a combination of both types of contracts. Projects investigated include petro-chemical (29%), civil (17%), institutional (13%), high-rise apartment buildings (4%), commercial (4%) and others (33%). Claims analyzed involved prime contracts (between owner or representative and general contractor) or subcontracts (between general contractor and subcontractor), with the majority of them involving private sector ownerships. In some cases, claims were as high as the original contract value. A similar study carried out by Goyal (1996), also in western Canada involving 24 projects from both the private and public sector showed that 20 of these projects had increases in the scope of work due to changed conditions from those shown on contract documents, additional work, and errors and omissions in engineering leading to large overruns in cost and schedule. If these factors can be used in assessing the likely final cost of construction at time of bid, it will be a big step forward for owners in avoiding surprises by picking the most suitable contractor and also encouraging contractors to bid more realistically. This therefore calls for modified and improved methods in awarding construction contracts.

1.2 CANADIAN CONSTRUCTION INDUSTRY PERFORMANCE

There are primarily two divisions of the construction industry according to the Statistics Canada classification system (Statistics Canada, 2003). They are Building and Engineering Construction, each of which has a number of sub-divisions as seen in **table A-1** and **table A-2** in **Appendix A**. These statistics show that there is a large capital expenditure on Canadian construction each year. Using average figures taken from 1994 to 1997 by Statistics Canada, building construction accounts for about $51 billion (62%) and engineering construction about $30 billion (38%) respectively of the total expenditure on Canadian construction per annum. This research however is designed to focus on Oil and Gas engineering construction since it represents the most significant sector within the engineering construction industry where large sums of capital are invested (about $14 billion representing 46% of the total annual expenditure on Canadian engineering construction).

Considering the highest valued construction projects across Canada, six of the top ten projects are related to the oil sands development in northern Alberta, representing 60% of this total (Industry Statistics – Canadian Construction Association, (2002)). According to this source, oil sands-related projects will account for over $45 billion in construction GDP from the mid 1990s to the mid 2010s. These top ten valued construction projects, either currently underway or in the planning stages are shown in **table A-3** in **Appendix A.** Alberta was chosen in particular for the study because it is the province that dominates in the oil and gas engineering construction sector of the construction industry. Besides, the motivation to undertake the research in the oil and gas sector is because cost overruns within the sector in Alberta are commonplace. Furthermore, there are many companies in Alberta that buy or sell oil and gas engineering construction services and would be able to provide enough data for the purpose of this study.

1.3 RESEARCH OBJECTIVES

The objectives of this research are as follows:

- Explore current industry practices in the construction contractor and subcontractor selection process through competitive bidding and other approaches by owners, consultants (for example, engineers) and contractors within the oil and gas engineering construction sector of the construction industry in Alberta.
- Seek professional knowledge of experts familiar with current industry practices in the research field of study to determine the factors that account for the difference between bid price (raw or adjusted) and the likely final cost (cost to the owner) of construction.
- Quantify the cost impacts associated with the final cost determining factors under different project conditions per contract type.
- Develop generic models using the impact levels of these factors in assessing the likely final cost of construction at time of bid as a means of improving, in particular, the low bid award procurement system in competitive construction bidding and contracting.

1.4 RESEARCH APPROACH

Literature on construction bidding and contracting reveals that bid price (raw or adjusted) plays a significant role in determining which contractor or sub-contractor is selected to execute a given project. However, there is evidence to suggest that the final installed cost to the owner is usually different from the price at which the contract was awarded. The researcher therefore needed to understand current industry practices in the contractor or sub-contractor selection process and to ascertain how significant the difference is between bid price and final construction cost to the owner.

In this respect, a pilot study was conducted through interviews using the modified Delphi technique, which constituted the first phase of the Delphi study. The purpose of this phase of the study was to:

1) Review current bidding and contracting procedures within the oil and gas sector of the construction industry in Alberta and the basis on which contracts are awarded.
2) Determine whether industry has any mechanism for assessing the difference between bid price and the likely final cost of construction at time of bid; and thereby establishing in part the significance or otherwise of the study.
3) Establish how significant the difference is between the low bid or estimate based on unit rates and the final construction cost to the owner.
4) Identify the factors that account for the difference between bid price and the final cost, which could be used in assessing the likely final cost at time of bid.
5) Determine the appropriate research methods to be used in the main phase of the Delphi study.

In the pilot phase, which consisted mainly of open-ended questions, the researcher developed an interview guide in order to focus on the research area and only asking supplementary probing questions when necessary. The interview guide, logical sequence and the wording of each question was designed and thoroughly tested. Any weakness in the interview guide was corrected before commencing with the interview.

In the main phase of the study, a survey (questionnaire) was used. This survey consisted of:

- A brief summary of responses from the pilot study
- Formulating new questions.

The purpose of this second phase of the study was to obtain the ranking of factors identified in the first phase as accounting for the difference between bid price and final construction cost and an assessment of the impact of each factor on the final installed cost to the owner. Questions in this survey were also tested, revised and re-tested before being mailed to the participants. The pilot and the main phase of the study involved 18 and 14 participants respectively.

1.5 RESEARCH PROCESS

The research process began with a preliminary literature review, a research proposal and a detailed literature review of works undertaken by various researchers and identifying gaps in existing knowledge. A two-phased Delphi method of approach was used consisting of the pilot and the main phase respectively. The pilot phase was used in part to validate gaps in the literature regarding the low bid award procurement system and narrowing down the area of research.

The main phase questionnaire was developed deductively from the pilot phase results. This process was guided by the literature review, research methods and through the guidance of the researcher's supervisor. The detailed research process is summarized in **figure 1-1** below.

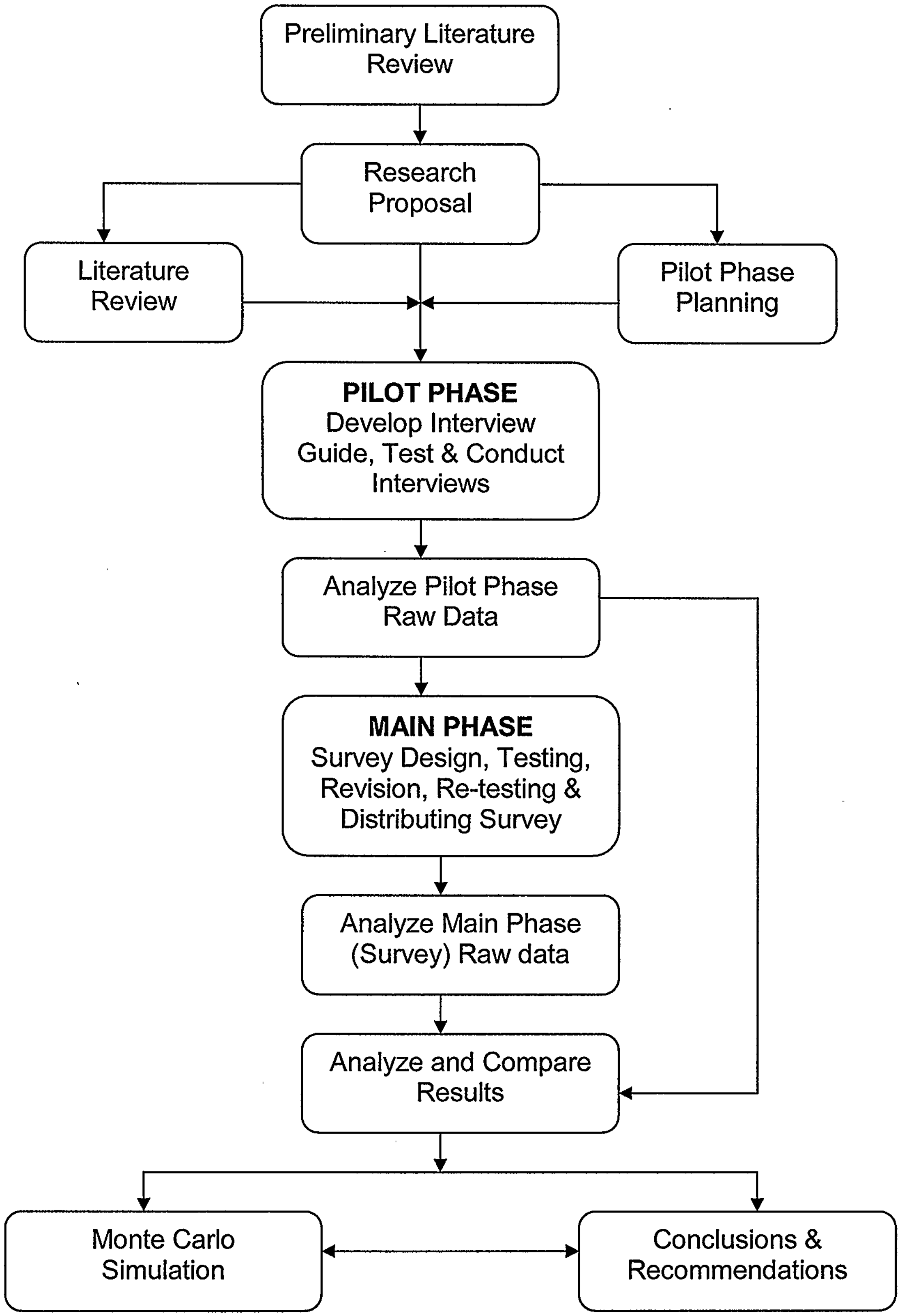

Figure 1-1: Research Process Flow Chart

1.6 PRINCIPAL ACHIEVEMENTS

Models that can provide predictions of the magnitude of the final cost of construction at the time of bid would allow bid organizers to better plan and budget for the actual cost of construction projects. Although this research could not result directly in the development of models that can be used to assess final cost of construction at bid time, it provides a foundation upon which future research can be done to develop such models. Data collection for this study was done in two stages –the pilot and the main phase respectively.

The pilot phase, which generally sought to review current industry vendor selection practices, resulted in the following principal achievements:

- Vendor selection typically involves the use of the competitive bidding process, which begins with pre-screening and pre-qualification of vendors. This is followed by a formal request for the submission of bids by the pre-qualified vendors and bid evaluation by the bid organizers. Sometimes, recommended bidders for contract award are made to undergo a pre-award interview. It was, however, discovered that owners or their agents select vendors to a lesser extent through nomination. This is usually based on long-term working relationships such as alliances or partnership agreements. Here, the terms and conditions of the contract are arrived at through negotiation.
- There are two main bidding philosophies in practice within the construction industry: 1) Submitting "cut-prices" just to win the contract and follow it up

by playing games during project execution in order to recover losses due to opportunities that might have been gambled with in achieving a low bid through the issue of change orders. 2) Taking chances to either win or lose the contract by submitting a fair or realistic bid based on market conditions. These philosophies confirm the phantom and the fair bidder types described by Crowly and Hancher (1995).

- The award of construction contracts are typically made to the lowest technically compliant bidder (raw or adjusted bid price). This practice seems to drive the submission of "cut-prices" by some vendors. On the other hand, price is considered as a major factor among other predetermined bid evaluation factors that receive a much heavier weighting in selecting a bidder for contract award.
- Since there is no estimate that is 100% accurate, there is always a difference between bid price, or estimate based on unit rates and final cost of construction to the owner. However, it has been established that the difference in cost is usually higher for the low-bid system of contract award.
- Based on the assertion that growth in cost is never zero, the factors that account for the difference between initial price (estimate) and final cost were obtained and coded into primary and secondary cost categories, which was used in designing the main phase questionnaire.

The main phase of the study, which involved assessment of weightings and quantification of cost impacts, yielded the following major achievements:

- Respondents weighted the factors, which influence final cost. Generally, there was agreement on how critical these factors are in accounting for the difference between initial estimate and final cost. Overall, the level of influence of these factors on final cost for each contract type (stipulated price, unit price and cost plus contracts) ranges approximately from "somewhat critical" to "very critical".
- Besides establishing how critical these factors are in determining final cost of construction at time of bid, the results of the survey provide the impacts (percent) associated with these factors in relation to each contract type and project condition (perfect, likely and outrageous). Although there is a wide range of variability associated with the impacts besides the approximations used in dealing with the cost factor overlaps, it provides useful information to bid organizers in being aware of the significant level of cost increases associated with each contract type and their respective confidence levels.

This thesis in general has provided increased understanding of practices and trends in the Oil and Gas engineering construction market place. Given that Oil and Gas construction accounts for about 46% of the total construction in engineering, any improvements in the efficiency of the vendor selection process has the potential of large cost savings besides improving the Canadian economy.

1.7 ORGANIZATION OF THESIS

There are six chapters in this thesis and they are organized as follows:

Chapter 2 is a review of relevant literature on bidding and contracting practices in the construction industry in general. It provides vital information relating to some industry games that are played during the bidding process. Contracting strategies and some types of competition-based bid award systems in use are also discussed. **Chapter 3** provides a review of literature relevant to construction cost assessment (predictability). Vital subject areas covered include price determination through cost estimating, importance of an accurate cost estimate, estimating pitfalls that result in differences between initial price and final cost of construction to the owner, and some industry achievements in the development of predictive models. Based on this review, a theoretical model for assessing final cost of construction at time of bid was proposed together with the research questions that drive the data collection approach. **Chapter 4** presents the research methods adopted in undertaking this research. It sets forth the reasons for applying the two-phased modified Delphi technique in data collection; the first phase of which was to narrow down and gain a deeper understanding of the topic through industry practices, and also to help determine which type of survey instrument to use in the second phase. **Chapter 5** presents and discusses the results of both the qualitative and quantitative data analysis. The key findings from the study are compared with those found in the literature (how they agree or disagree with those stated in literature). **Chapter 6** concludes with a summary of academic contributions to the body of knowledge, industrial application of research findings, research limitations, and recommended areas for further study.

CHAPTER TWO CONSTRUCTION BIDDING AND CONTRACTING

Vendors (General Contractors and Subcontractors) will typically be required to go through a process when they are asked to submit a price or proposal for a given piece of work. This means that in order for a project to be undertaken, goods and services must be procured by the client. Just as the client will have a strategy for procuring these goods and services, in much the same way a contractor will also have a strategy to win a given contract, which may involve fair or foul play. In this chapter, we will discuss bidding procedures from when contractors are considered for a given project until the contract is signed between the client and the selected contractor.

2.1 THE CONSTRUCTION BID AND BIDDING PROCESS

A construction bid is an offer to perform specific work and/or duties in return for a specified price (Cook 1985). It is an opportunity for making money or losing it. The contractor can lose it either because he does not win the contract, and so lose his bid costs, or he does win, but costs exceed the estimate (price) and he may not be able to recover the deficit (Marsh P. D. V 1987). The obvious preferred situation is to win the contract and execute it at a reasonable level of profit. The element of profit or loss cannot be stressed too highly. Quite obviously, if a profit is not made, then the contractor will incur a loss and will eventually be forced out of business (Sayers 1991).

In construction bidding and contracting, contract formation in the construction industry is usually accomplished through the bidding process and the process involves the following stages (Samuels 1996):

- **Preparation of the Bid Documents**: Most, if not all, of these documents will be prepared by the design team. These documents typically include the drawings, specifications, agreement, general conditions of contract, special or supplementary conditions, instructions to bidders, and the invitation to bidders.
- **Solicitation or Invitation of Bids**: In the private sector, almost all invitations to bidders contain a statement that the lowest or any bid may not be accepted and that the owner reserves the right to accept or reject any bid. Public bodies may be required by statute or charter to follow certain rules in the evaluation and acceptance of bids, which usually requires that the lowest compliant bid from a qualified contractor be accepted. The statement that the lowest bid may not necessarily be accepted cannot always be taken at face value because the owner's discretion to reject a low bid may be limited by statute (in the case of public bodies), by regulation (if bids are submitted through a bid depository) or by common law in some jurisdictions. In jurisdictions that limit the owner's rights of acceptance and rejection, the invitation is the owner's opportunity to set out the factors to be used for acceptance and rejection. Methods of bid solicitation are discussed in section 2.2.

- **Pricing by the Contractors**: Contractors must work quickly to estimate all costs (direct and indirect) associated with the project. Very few general contractors have the expertise to perform all the work with their own forces, and out of necessity they rely on subcontractors not only to perform the work but also to price it. Similarly, the subcontractors must often obtain prices from their own suppliers and subcontractors before submitting their prices to the general contractors. To avoid having their prices shopped around, contractors, subcontractors and suppliers submit their prices as late as practicable. The result is that many sub-trade prices are delivered to the general contractor on the same day (or in extreme cases, in the last hour) that bids are due. The general contractor often cannot investigate or evaluate sub-trade prices before deciding whether or not to use those prices.
- **Submission of Bids**: Submission of the bid usually requires the contractor to comply with instructions on timing, form and content. If the bid is late, the owner may be required to reject it. Requirements as to form and content usually mean that the bid cannot contain substantial exclusions or qualifications. The owner may be prevented from accepting a non-compliant bid by statute (for public bodies) or by regulation (for members of a bid depository).
- **Evaluation by the Owner**: Evaluation of bids by the owner is usually done with the assistance of consultants (for example, engineers) or construction managers. The owner will consider whether the lowest

compliant bid is within the construction budget and will evaluate cost-saving alternatives proposed by the bidders. Another factor considered during the evaluation phase is the reputation of the low bidder and its ability to perform the work. Recommendations are sometimes made that a particular bidder be rejected, based on the reputation of the bidder or on past dealings. Rejected bidders have sued consultants for giving such advice, basing the action on defamation. However, as long as the recommendation is made in good faith and without malice, the consultant or construction manager is protected by the defence of qualified privilege.

- **Award of the Contract**: The award of the contract constitutes the acceptance of a final offer and thus crystallizes contractual rights between the owner and the successful bidder. It may also crystallize rights, obligations and liabilities of other parties, including sureties. The award of the main contract will also affect subcontractors and suppliers whose prices have been used in that those prices will be irrevocable due to reliance on them by the general contractor. This is an over-simplification in terms of contract award since the process may be more complex than this.

2.2 TYPES OF BID CALL

The type of construction contract to be employed, complexity of project, procurement policies of the owner and the market place, among other factors are vital considerations in the selection of the type of bid call to be used. There are basically three types of bid calls namely Bidding, Request for Proposal and Negotiation (Hartman 2003).

2.2.1 Bidding

This is the most traditional and best understood way of selecting a contractor. It is the most readily accepted way of selection although it does not necessarily give the best deal or result in the selection of the best contractor. The criterion for selection is usually lowest price. If the purpose of bidding for supply of goods and services is to obtain value, the lowest price is not a guarantee that this will be achieved. Even when the buyer has specified what is required and has written a "watertight" contract for its delivery, the lowest price can lead to a higher final cost to the owner. There are typically three options available to the owner in the bidding process which is briefly described as follows:

1) **Open Competition**: This involves open invitation to all potential contractors who wish to participate.
2) **Selective Competition**: This is a form of pre-qualification whereby the owner limits the bidding to a select group, any of which would be acceptable, and who are comparable in ability.
3) **Pre-qualification**: This involves an invitation to bidders any of whom would be acceptable based upon a pre-screening process and upon response to an open invitation to submit a pre-qualification bid. In this case, a minimum statement of pre-qualification requirements is designed

to establish the abilities of contractors to satisfy the requirements of the specific project prior to submitting a formal bid.

The particular option of the bid call used remains the owner's prerogative.

2.2.2 Request for Proposal (RFP)

An RFP is a request for some form of proposal to solve a problem. This implies that the solution(s) proposed by potential contractors form part of what the owner will assess in the selection process. The implication is that there is more being considered than just price. It is good practice to specify clearly what is going to be assessed. This often includes proposed personnel, proprietary technologies, technical solutions, project delivery plans and more. Increasingly, clients are looking for other information such as projects of similar nature which can be referenced and the track record of the contractor in claims, safety, labor relations and so on. According to Hartman (2003), the RFP process is probably best used to screen contractors on a long list and to then interview and negotiate with the best or most interesting respondents. It is not unusual to see an owner negotiate with two or more proponents.

The request for proposals are evaluated on the basis of pre-established weighted evaluation criteria as outlined in the request and the contract is awarded for best overall value where price is only one factor (Supply and Services Canada 1983).

2.2.3 Negotiation

Selection of a contractor and award of a contract may be based on consideration of a single potential source. Or it may be based on discussions with the best of a number of bidders or proponents who responded to an RFP. A successful negotiation is one in which all players feel they have a good fair deal.

2.3 BIDDING AND CONTRACTING PRINCIPLES

By definition, a contract is essentially an agreement between two or more parties to do or to refrain from doing something (Haswell et al. 1989). The requirements of a valid contract are discussed later in this chapter.

In rendering its decision in Ron Engineering, the Supreme Court of Canada confirmed a new principle in the law of tendering and contracting in Canada. The principle is that there are two separate contracts arising in the tendering process. The first is "Contract A" (the contract of irrevocability), that deals with the tendering phase. When a bid is submitted on an irrevocable basis pursuant to the conditions in the owner's request for tenders a "Contract A" is formed. As many "Contracts A" will be formed as the number of tenders submitted. The second is "Contract B" (the construction contract itself) that is formed between the owner and the successful bidder when he (the successful bidder) signs the official agreement to perform the works (Supreme Court Reports 1981; Marston 1996).

2.3.1 Requirements for a Valid Contract

There are six basic requirements that must be satisfied in order for an agreement to constitute a valid contract (Betty 1993; O'Reilly 1996; Samuels 1996):

1. **Intention to Create Legal Relationship:** It must be clear that the parties intended to create a legally binding agreement. There can be no contract unless the parties' intention to enter into an agreement enforceable at law can be demonstrated.
2. **Genuine Consent:** For a contract to be valid, the consent of the parties must be genuine. Consent obtained under duress or by undue influence can make a contract invalid at the application of the weaker or injured party. Consent obtained by fraud or misrepresentation or through a mistake in facts is not genuine, although it does not necessarily follow that a court will hold that the contract is invalid.
3. **Legality of Purpose:** A contract may be held to be illegal by common law or by statute. Contracts deemed illegal by common law rarely arise in engineering situations. Agreements to commit a crime or to hinder the administration of justice or to injure public services or to defraud in revenue or to attempt corruption are examples of actions illegal at common law. However, illegality by statute sometimes arises in engineering contracts. A contract may be legally entered into, yet its performance may be in breach of a statute or regulation. Such a contract will be void and unenforceable at law and neither party can claim relief under it.

4. **Legal Capacity:** Not all persons can enter into a legally binding agreement. Infants, those who are insane or under the influence of alcohol or narcotics, bankrupts and persons in legal custody cannot legally enter into a valid contract.
5. **Offer and Acceptance:** A contract is formed when one party makes an offer to another party and is unconditionally accepted by the second party. A qualified or unconditional acceptance does not form a contract but constitutes a counter-offer. This in turn requires an unconditional acceptance of the counter-offer by the first party before a contract can be said to exist. An offer and an acceptance could be in writing, oral or implied by conduct. Where there is an agreement and it can be demonstrated that both parties were aware that their actions could be construed as forming a contract, a legally binding contract would be held to exist. Under English common law, an invitation to tender is not an offer but an indication of willingness to trade. However, in Canada, an invitation for bids is legally an offer as illustrated by the Supreme Court of Canada landmark Ron Engineering case. Primarily the case concerned the right of a bidder to withdraw a bid without penalty when the bidder discovered an error in pricing. The court held that, once tenders had been submitted, a unilateral contract imposing obligations on both parties came into existence for the duration of the bid validity period.
6. **Consideration:** This means something of value, however small, given or promised by each party to the contract. The primary consideration given

by the owner in a construction contract is the promise to pay the contract price and that given by the contractor is the promise to perform the construction. It is not necessary that the consideration given by each party be of equal value. A promise without consideration is a gift, and courts will not enforce a promise to give a gift. Construction contracts may be amended during performance because of changed circumstances. Each amendment must be supported by consideration or else it will be unenforceable. Such problems happen on construction projects where one party demands changes to the contract in midstream.

2.4 GAMES IN CONSTRUCTION BIDDING

Games are probably played in most industries if not all, where there is competition. In a game, there are others present who are making decisions in accordance with their own wishes, and these players must be taken into account. While you are trying to figure out what others are doing, they will be trying to figure out what you are doing (Davis 1997). Where there are no rules to regulate games in a particular industry, professionalism demands an ethical approach. When it comes to the playing of these games, the construction industry is no exception.

2.4.1 Ethical Issues in Construction Industry Games

Of all the phases in a construction project, the bidding phase is perhaps the most vulnerable to ethical concerns. This is because it is open to the outside world's zealous competition and the resulting, often ruthless strategies (Cook 1985). By Cook's definition, ethics is another name for fair play, the control of one's conduct to avoid any form of injury to other contestants. He asserts that daily experience and observation reinforce that being ethical is the rule in bidding and being unethical is the exception. There are various ethical problems associated with the bidding process (Cook 1985; Fisk 2000; Hinze and Tracey 1994; Hartman 2003), which are discussed as follows:

1. **Bid Shopping:** This is asking a sub-bidder for a special price, lower than the subcontractor's quotation to other bidders. Bid shopping can be either pre- or post-bid. The general contractor or subcontractor typically initiates the pre-bid shopping. Where it is initiated by the general contractor, he might lead subcontractors to believe that lesser bids than theirs have been received. Or the prime contractor may actually reveal low sub-bids in an attempt to get better prices. The fear that their bids may be disclosed during the bidding period explains partially why many subcontractors do not submit their final bids until the last minute. Where the subcontractor initiates it, he obtains information about the lowest price that has been bid by the competing subcontractors. A subcontractor who initiates bid shopping will typically seek the cooperation of one of the general contractors that is intending to submit a bid on a project. He must identify a general contractor who is willing to disclose the bids of other subcontractors. If the subcontractor's bid is not the lowest, he will then assess the merit of submitting a reduced bid. The general contractor

solely initiates post-bid shopping, also called bid chopping or chiseling. After being notified of selection, he shops around for other potential subcontractors and offers to substitute them in the general contractor's bid only if they will underbid the subcontractors originally used in determining the bid price. This is also an unethical situation in which some contractors engage, primarily as a means of increasing profits on a project or to cover an error made in the bid or for whatever other reasons.

2. **Nominal Bid Submission:** Another situation is where a contractor is unable to submit a bid on a project but at the same time does not want to upset the client or consultants. The contractor in this case may submit a nominal bid by getting a "safe" higher price from a competitor and then submitting it as a bid. This verges on price rigging, but with the intent of saving effort and trying not to upset a current or prospective future client by saying we are not interested in their work. Under this condition, a contractor would call on favorite subcontractors who are too busy to support the bid to take similar action. If the nominal bid is submitted with appropriate care and trust between the competitors who are willing to exchange this type of information, then the owner will not even know it has happened.
3. **Collusion:** This is deliberate rigging of a bid by the bidders such that the outcome is predetermined. In this case, the collaborating parties decide on who will win the bid, which will usually be at a margin significantly above market prices. This practice is generally illegal in most jurisdictions.

4. **Alternative Bid:** There is the possibility of saving the client a significant amount of money with an innovative solution. If the bid process precludes submission of “non-compliant” bids, it stands to be possibly rejected by the owner. However, if the bid is attractive, the owner may be tempted to negotiate with the innovator or possibly request new prices from all of the bidders based on the innovation. This would prove difficult in Canada because of legal precedent although it may be legal in other jurisdictions . Despite this, it has been known for owners to take advantage of the proprietary information submitted in such bids.

2.4.2 The Price-Cutting Game

Park (1979) is of the view that the impact of the low-markup, high volume business on the construction industry cannot be measured accurately, but millions of dollars in profits are undoubtedly sacrificed each year because of this type of game situation. A job taken at a price closely approaching the direct job costs benefits no one. The contractor who gets the job makes nothing at his minimal price, and those who bid the job without getting it merely incur the additional costs of preparing their unsuccessful bids. The net effect on the industry as a whole is worse than if the jobs were never offered, for it results only in additional costs with no compensating profits.

2.4.3 Unbalanced Bid Games

Front-end loading, a typical form of bid unbalancing has been with us for a long time and will probably remain with us for the foreseeable future (Roberts 1994). Front-end loading is a game situation where a vendor would over-price items of work to be performed early and under-prices items of work to be performed late during construction; thus the pricing approach will not reflect reality. This bid unbalancing technique is used by vendors to enhance cash flow or to obtain early job financing (Roberts 1994 and Moselhi et al. 1991).

Another situation of bid unbalancing is where a vendor, in anticipation of increased quantities of a particular work item during construction, would submit extremely high unit rates for these items of work and reducing the unit rate for items of work where there are likely to be reduction or no change in quantity. This would result in a bid price that is the same; however, if those anticipated quantities do increase substantially, the vendor will receive greatly increased revenue. The obvious conclusion is that the contractor is attempting to make a windfall profit. In this situation, as well as in front-end loading, the vendor would definitely have the bidding advantage over other bidders where price is the sole criterion or predominant consideration. It is therefore necessary to prevent bid unbalancing wherein overspending takes place in the early stages of construction (Sutliff and Zack 1987). While prevention may not be entirely possible, it can be checked during bid evaluation by comparing various components of contractors' estimates to that of the owner or consultant. Owners and consultants need to be aware of unbalanced bid games played by vendors and be on the lookout during bid evaluations. Sometimes contractors' risk expected future "windfalls" to discount bids so that they may get the work. If the "windfall" does not materialize – they lose money.

2.5 CONTRACT STRATEGIES AND CONTRACT TYPES

There are no prescribed formats for choosing among construction contracts. In the construction industry, the choice of contract form and type is largely driven by the risk each party to the contract would assume for the kind of work under consideration and it could produce very significant effects on project performance. Ibbs et al. (1987) state that the contract form is undeniably a major determinant of project success or failure. Construction Contracts have three basic classifications based on the mode of reimbursement (Cheng 2000), which are:

- Stipulated price contracts
- Unit rate contracts
- Cost plus contracts.

It is also possible to combine any two or more of these types of contract pricing indicated above. The following sections define each of the contract types, important factors that influence the choice of a particular type, and their merits and demerits.

2.5.1 Stipulated Price Contracts

This is a type of contract in which the contractor agrees to perform construction work at a stipulated price set forth in the contract documents. The only changes allowed to a stipulated price contract are for extras or change orders. This contract approach should be used when the scope and quality of work can be defined in sufficient detail, which minimizes the owner's risk as well as the project execution schedule. The contractor bears the total risk associated with the construction of the project. In Collier's (1982) view, a contractor can only minimize his risk of loss in this kind of contract by:

1. Making the best possible estimate of construction costs (including overhead and profit) before bidding.
2. Bidding according to his estimate and not below the estimated costs.
3. Doing the work for less than the estimated costs.

The use of stipulated price contracts is common to both private and public sector projects. Bids are requested based on a complete set of drawings and specifications, thus allowing for easy comparison of bid prices and fostering competition. The stipulated price approach offers bidders maximum flexibility to manage the project and also minimizes an owner's control during construction.

Dingle (1997) presents some advantages and disadvantages of stipulated contracts as follows:

Advantages

- Initial contract price is known at the outset (although this may prove otherwise at the end of the project).
- Contractor assumes greatest risk (owner advantage). This is because if the contractor, for example, under-prices the work, the owner will not be under obligation to compensate him even if he makes a loss.
- Strongest motivation of the contractor due to his commitment on time and cost.
- The high degree of contractor responsibility means simpler contract control by the owner.

Disadvantages

- Contract award may be delayed later than with other types because of the need to define work fully, so that the tender period will be longer. And if the work is really not fully defined, the result may be "change orders" with its associated time and cost impacts.
- Owner's ability to influence performance within the terms of the contract is reduced because of the extent of the contractor's responsibility.
- Contractors will usually include allowances for contingencies in the bid price, which may be high.
- The contractor will tend to choose the cheapest and quickest solutions, making technical monitoring and strict quality control by the owner essential.

2.5.2 Unit Rate Contracts

Unit rate contracts are a viable alternative to stipulated price contracts and permit commencement of construction work, when design is incomplete. Huston (1996) gives a detailed description of unit rate contracts as follows:

Unit rate contracts require an accurate description of the complexity of the work as well as an estimate of the probable quantity of units. The units of work need to be well defined although the total quantities are uncertain due to incomplete engineering, and it is used on projects involving large quantities of repetitive units or as a preferred approach, as in the United Kingdom for civil and building works using the "Standard Method of Measurement".

In a unit rate contract approach, the seller (contractor) agrees to furnish each unit of work or product defined by a buyer (owner) for a fixed price per unit. There are usually ranges of estimated quantities of work included. Here, the seller assumes the risk of the cost per unit within the specified range and the buyer assumes the risk of quantity change in the number of units beyond the specified range. Unit rate contracts can be priced at current day rates with provisions for adding cost escalation to the units when actual escalation costs are known. Changes in design, which increase complexity, may lead to requests for increased unit rates. These requests for increased rates can be significantly higher than the original unit prices since the contractor may not have to bid the changes competitively (Huston 1996).

Advantages

- There is risk sharing - the owner assumes the risk of change in quantity and the contractor assumes the risk of cost per unit of work item or product.
- Good design definition is not essential – typical drawings can be used for the bidding process.
- Bidding is speedy and inexpensive, and an early start is possible.
- Flexibility – depending on the contract conditions, the scope and quantity of work can be varied.

Disadvantages

- Difficult to estimate final cost at the outset, since quantities are estimated based on incomplete engineering.
- Additional site staff is needed to measure, control and report on the cost and status of the work.
- Biased bidding and front-end loading may not be detected.

2.5.3 Cost Plus Contracts

In a cost plus contract, the contractor agrees to use his best effort to perform the work. All costs including materials, equipment and labor are reimbursed at actual cost (usually based on invoices). The contractor earns a fee based on a fixed amount or percentage of actual cost of goods and services or some form of incentive plan. Cost plus contracts are appropriate where, due to an incomplete or very complex design, a contractor would be unable to give a stipulated price without including a large contingency for unknown factors. This type of contract can also be employed in a fast-tracked manner, phasing and integrating design with construction, which may theoretically reduce overall project duration relative to stipulated price contracts. An empirical study conducted by Pedwell et al. (1998) on oil and gas projects with more than 30 industrial practitioners concluded that the reduced project duration in fast-tracking increases total project costs and risks.

Dingle (1997) and AACE International (1999) present some advantages and disadvantages of cost plus contracts as follows:

Advantages

- Associated with flexibility in dealing with changes (which is very important when the job is not well defined), particularly if new technology development is proceeding concurrently with the design.
- Contract award may be earlier than with other types because the scope of work does not have to be well defined, so the bid may be sooner (i.e. before design is complete).
- Useful where site problems such as trade union actions like delays or disruptions may be encountered.

- Owner can control all aspects of the work as the contractor only performs the work under the direction of the owner and is reimbursed at cost based on invoices.

Disadvantages

- Difficulties in evaluating proposals – strict comparison of the amount quoted may not result in selecting the "best" contractor or in achieving the lowest project cost.
- Contractor has little incentive for early completion or cost economy since his performance is reimbursed at cost with an agreed margin for profit.
- Contractor may assign its "second division" personnel to the job, make excessive use of agency personnel, or use the job as a training vehicle for new personnel due to contract flexibility.
- Owner carries most of the risks and faces the difficult decisions as the contractor only performs the work under the oversight of the owner.

2.6 COMPETITION-BASED BID AWARD SYSTEMS

Competitive bidding is one option of a formal process for the procurement of goods and services. The purpose of competitive bidding is to stimulate competition and usually to obtain the lowest price for the work or service needed. The competitive bidding process requires that bids be evaluated and awards made based solely upon bid specifications, terms and conditions contained in the invitation to tender, and according to the bid prices offered by vendors that may affect contract performance.

2.6.1 Low-Bid System of Award

This is the traditional system of awarding construction contracts with price as the sole criterion or having the heaviest weighting. This may account for the price-cutting game played by bidders. Innovative organization and technologies could also give contractors competitive advantage resulting in low price offers (Rapp 1997). While these views hold some truth, there are views expressed by others like Park (1979) that the lowest price for a job frequently means, naturally enough, that the job will be carried out under the lowest standards possible. This may not be necessarily true. Consider for example a situation where a "watertight" contract is written. If the owner is very judicious in enforcing the terms and conditions of the contract, the contractor will be forced to execute the job to meet required standards. In the event of the owner not paying attention to quality issues despite its stipulation in the contract, then the contractor may get away with shoddy work.

There may, however, be circumstances under which a contract may not be given to the lowest bidder on grounds of certain contract conditions. For example, there was a case in Iowa where a low bidder lost to the next highest bidder due to preference for a local contractor on a public project (Engineering News Record 2002). This is also illustrated in the Canadian context by the Chinook Aggregates Ltd. versus Abbotsford Municipality District (Construction Law Reports 1990) case decided by the British Columbia Court of Appeal. In this case, the municipality invited bids on a gravel-crushing contract. The municipality had an "unwritten" policy of preferring local contractors. The British Columbia Court of Appeal held that the provision that "the lowest or any bid will not necessarily be accepted" did not override the implied duty to accept the lowest bidder. The court ruled that the owner had to adhere to the established custom of accepting the lowest bid unless the bid documents expressly stated that the bids would be evaluated on other criteria such as preference for local contractors regardless of who turns out to be the lowest bidder.

2.6.2 Average Bid Method of Award

The competitive bidding process for awarding construction contracts is typically based on the low-bid method in North America. With this method, the vendor submitting the lowest bid receives the right to the construction contract. Its main advantage is that it compels contractors to continuously try to lower costs by adopting cost-saving technological and managerial innovations. These savings are then passed on to the owner through the competitive bidding process. A vendor who has either accidentally or deliberately submitted an unrealistically low bid cannot adhere to such a price and at the same time expect to complete the project according to plans and specifications, and also make a reasonable profit. This often results in excessive claims and disputes during construction that lead to schedule delays, compromises in quality, and increased costs (Ioannou and Leu1993). Hence the development of the average bid method, which is in use in the United States, Australia, Italy and Taiwan. In the United States for example, there is the claim that the average bid method encourages Florida contractors to bid a true and reasonable cost (Anonymous 1998).

Ioannou and Leu 1993), besides some of the ideas expressed above describe how the average bid method works as follows: Some users of this method use the arithmetic average or weighted average, while others use the average of the remaining bids after all bids that differ more than a certain percentage from the average of all other bids are eliminated. The Florida Department of Transportation for example throws out the high and low bids and averages the rest if there are more than five bids, averages all bids if there are three or four and re-advertises the job if fewer than three bids are received (Anonymous 1998). Most commonly, the winner is the bidder whose price is closer to and less than the arithmetic average of all bids submitted.

The basic advantage of the average bid method from an owner's point of view is that it safeguards against signing a construction contract for an unrealistically low bid price that almost certainly will lead to adversarial relationships during construction. Similarly, contractors are theoretically protected from having to honor a bid containing a gross mistake or oversight. The basic setback of this method is that it does not necessarily promote price competition that leads to lower costs for the owner. It is easy to see that a technological or managerial breakthrough that results in major cost savings will not necessarily be passed on to the owner in the form of low prices, unless this breakthrough is known to be available to all bidders. Another pitfall with this method is collusion among bidders. However, a departure from the low-bid method has the potential to improve the longevity of construction firms, the elimination of accidentally or deliberately low bids, and the improvement of relationships between owner and contractor during construction.

2.6.3 Value-Based Method of Award

This method of approach is currently used in the United States by some government agencies and is covered by federal acquisition regulations. Increasingly, private owners are being encouraged to use this approach.

The value-based contracting approach was developed as an alternative to low bid contracting. According to Gransberg and Ellicott (1997), best-value contracting focuses on selecting the contractor with the offer most advantageous to the client, when price and other factors are considered. The evaluation criteria can be quantifiable in terms of dollars or weighted scores. The solicitation must specify the evaluation criteria to be used. Criteria may include technical excellence, managerial capability, financial capability, personnel qualifications, prior experience, past performance and more.

While not specifically scoring cost, the contract price is used to compare the technical value versus the cost of the added value of various proposals, which is called the cost-technical tradeoff. The client, in principle, must show that a more expensive proposal provides a corresponding increase in value. Best value contracting offers the following advantages over low-bid procurement:

- Key players agree on important project criteria early in the procurement process.
- The process focuses on quality and value rather than only on initial contract price.
- It encourages contractor innovation and solicits alternative proposals.
- It meets the client's needs by selecting a contractor best able to satisfy those needs.

Some disadvantages include:

- The solicitation package requires more time and effort to prepare properly.
- The evaluation process becomes more complicated and requires more attention to detail.
- The process increases the danger of bid protest and a subsequent delay in contract award.

A typical set of evaluation criteria is illustrated by Gransberg (1997) in **table 2-1** below:

Category	Weight	Proposal 1		Proposal 2		Proposal 3	
		Ranking	Score	Ranking	Score	Ranking	Score
Technical	30	2	60	3	90	1	30
Management	5	3	15	2	10	1	5
Financial	5	1	5	3	10	3	15
Personnel	10	2	20	3	30	1	10
Experience	15	1	15	3	45	2	30
Past. Perf.	15	1	15	2	30	3	45
Milestone	5	3	15	1	5	2	10
Pricing	15	1	15	2	30	3	45
TOTALS	**100**		**160**		**250**		**190**

Table 2-1: Example of the Weighted Scoring of Three Hypothetical Proposals

The table shows how three hypothetical proposals received by a client would be evaluated based on 1) technical approach, 2) management capability, 3) financial capability, 4) personnel qualifications, 5) prior experience on projects of similar nature, 6) past performance records, 7) projected performance milestones and 8) project pricing information. Gransberg does not define the evaluation factors but he does illustrate how the value-based method of contract award is carried out. In its simplest form, the process asks an interdisciplinary evaluation team (e.g. design engineer, architect, management consultant, accountant, construction manager, cost engineer, etc.) to merely rank each proposal from least responsive to most responsive, with the least responsive proposal getting a score of 1 and the most responsive receiving a score of 3 points. Each of the 8 categories of measures has a weight based on its individual importance to the owner and its overall contribution to the success of the project.

The sum of the weights equals 100. Therefore if a given proposal were rated best in all categories, it would receive a weighted total score of 300. It can be seen from the table that proposal 2 would be the winning proposal with the highest weighted score of 250.

CHAPTER THREE CONSTRUCTION COST PREDICTABILITY

3.1 PREDICTING THE FUTURE

Generally, bidding is concerned with predicting the future, since the vendor (contractor and subcontractor) must commit to a price and time schedule before the work is actually undertaken. In this regard, a vendor has to keep an accurate database of information drawn from previous projects for use on subsequent projects. Owners or project sponsors must do the same for comparison purposes, during bid evaluation, in assessing the reality of the price and time commitments proposed by bidders. Vendors therefore face a challenge of submitting winning bids if they are to survive and grow in an increasingly competitive market.

3.2 DEFINITION OF COMMON TERMS

The terms "cost" and "price" are used interchangeably in everyday life. However, they mean two different things in bidding and contracting. These and other definitions as they apply to construction bidding and contracting are presented below.

Cost: AACE International (1993) defines cost as the amount in money, cash expended, or liability incurred in consideration of goods and/or services. Costs may be direct or indirect, and are further defined by AACE International (1993) as follows:

Direct Cost: This is the cost of installed equipment, material and labor directly involved in the physical construction of the permanent facility.

Indirect Costs: These are all costs which do not become a final part of the installation, but which are required for the orderly completion of the installation and may include, but are not limited to, field administration, direct supervision, capital tools, start-up costs, contractor's fees, insurance, taxes and more. Indirect costs are also referred to as overheads. However, a study conducted by Semple (1996) revealed that there is very little understanding and/or agreement in the construction industry as to which costs should be classified as direct or indirect. It was also discovered during this study that indirect costs are not usually itemized but most often calculated as a percentage of direct costs.

Price: From the definition of contract sum (contract price), price is an amount representing the total consideration to be paid the contractor for services performed under the contract for construction (R. S. Means Co. Inc. 1991). Price determination considers business and other interests (e.g. profit, marketing, etc.) in addition to the inherent costs (Pietlock et al. 2001). The contract or final price paid to a vendor becomes the final cost to the owner.

Profit: This is the amount of money, if any, which a contractor retains after he or she has completed a project and has paid all costs for materials, equipment, labor, overhead, taxes, insurance, and more. The amount included in a bid for profit would typically depend on the size of the project, extent of risk involved, desire of the contractor to get the job, extent of competition and other factors (Peurifoy and Oberlender 1989).

Contingency: This is an amount added to an estimate to allow for changes that experience shows will likely be required. It may be derived either through statistical analysis of past project costs or by applying experience from similar projects. It usually excludes changes in scope or unforeseeable major events such as strikes, earthquakes, etc. (AACE International 1993). There may also be non-monetary contingencies in various forms such as alternative methods, "opportunities" in bid documents, pricing of units for expected changes etc.

3.3 BID PRICE COMPONENTS AND BIDDER TYPES

The basis of an estimate is the aggregate of all the direct costs (DC) and an added fee. This fee, or overhead and profit margin (OH + PM), as it is sometimes called, comprises the main office overhead, general and administrative costs, soft costs and profit. These costs can be separated into overhead or indirect cost (OH) and profit margin (PM) since they can be viewed differently; OH is company-imposed, and PM is an amount whose value is essentially the result of a management decision. Some estimators and managers may differ about what expense belongs in which allocation, but this simplified classification divides the price into three basic elements, each driven essentially by its own set of factors (Silberman 1993). Combined, these three main components comprise the total bid price, which may become the contract price if no adjustments are made:

$$\text{Bid Price} = DC + OH + PM \longrightarrow \text{Equation 1}$$

But the total cost of the project can be defined as:

$$\text{Cost} = DC + OH \longrightarrow \text{Equation 2}$$

Substituting equation 2 into equation 1 yields:

Bid Price = Cost + PM ⟶ Equation 3

In contracting, therefore, the area where profits must be made by a vendor is the area between the estimated cost of doing the job and the amount bid for the job (bid price). It is worth noting that bidders use certain strategies that may or not be fair in pricing. For example, some contractors upon finding a set of poorly defined plans and specifications will purposely bid low (i.e. zero or negative profit) knowing that many change orders will be necessary and will yield a handsome profit (Halpin and Woodhead 1998). That is, they will bid low to get the award and then negotiate high prices on the many change orders that are issued. However, change orders do not guarantee profits, as stated by Halpin and Woodhead. It can rather be said that a bidder seeing a poor design and anticipating the issue of change orders during construction may bid a low amount expecting to recover money that might have been "gambled" with at time of bid to achieve a lower bid price. Crowley and Hancher (1995) have identified three types of bidders and they can be classified as phantom, mistaken and fair based upon their bidding strategies.

Phantom bidders consistently submit bids that are lower than other bids received on a project. Mistaken bidders submit unusually low bids due to an error or omission. Fair bidders consistently target the market value with their bids. Minor issues relating to judgment or assumptions may account for the differences in bids of fair bidders. The phantom bidder takes the job at the low bid price hoping that change orders will be issued during construction, which will eventually increase the final cost of construction to the owner if he (contractor) is successful in his quest.

3.4 COST ENGINEERING AND ESTIMATION

Cost engineering answers the questions: how much does it cost? How long will it take? And later, does it really cost and take as much and as long as predicted? (Samid 1990). According to Samid, the cost engineering components that handle these questions are cost estimation, scheduling, and cost control. Value engineering was not considered by Samid but should be part of the cost engineering process.

Cost estimation provides the foundation to cost engineering and by definition, a cost estimate is a compilation of all costs of the elements of a project or effort included within an agreed upon scope (Uppal 2003)). Again, an estimate is essentially a prediction (Lorenzoni and Clark 1985). This implies that an estimate is a forecast of the way something will be built in terms of time and cost. In terms of cost, an estimator, based on a defined scope, translates a design into a dollar value by applying unit costs to the quantities or by use of other techniques. In doing this, estimators are predicting what will be paid for when it is purchased and/or installed. Therefore assessing final cost of construction at time of bid, which is the focus of this research, is not a new concept. It is rather intended to aid in adjusting estimates produced using traditional (Price = Cost + PM) procedures to reflect what the likely final cost of construction would be at time of bid.

3.5 PRICE DETERMINATION THROUGH COST ESTIMATING

Bid preparation requires the production of estimates by prospective bidders to which mark-ups are added to cover profits and overheads in arriving at the price. And owners also produce their own internal estimates for comparison and budgetary purposes, among others. There are various tools and techniques, which aid both bidders and owners in the production of estimates. While this thesis does not intend to go through the cost estimation process, it presents the types of estimates that are carried out in the construction industry, especially in the oil and gas engineering construction sector. A variety of estimating methods is available for use depending on the purpose of the estimate.

Literature indicates that there are three to five discrete categories of estimates. For example, Park and Jackson (1984); Jelen and Black (1983) and Ostwald (1992) classify estimates into three categories namely order-of-magnitude, budget and definitive (accurate) but there is no agreement in the accuracy ranges. Other authors such as Wideman (1995), Patrascu (1988) and AACE International (2003) describe five classes of estimates with variations in accuracy ranges as well. The classification system and accuracy ranges established by AACE International (**see table 3-1 below**) is adopted in this thesis since it was specifically developed for use in Engineering, Procurement and Construction

(EPC) for process industries (e.g. oil and gas industries) to which cost impact assessments will be compared during the analysis of the main phase survey results. The estimate class designations are labelled Class 1, 2, 3, 4, and 5. A Class 5 estimate is based upon the lowest level of project definition, and a Class 1 estimate is closest to the full project definition and maturity.

	Primary Characteristic	**Secondary Characteristic**		
Estimate Class	**Level of Project Definition** (As % of complete definition)	**End Usage** Typical purpose of estimate	**Methodology** Typical estimating method	**Expected Accuracy Range** Typical variation in low & high ranges
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to –50% H: +30% to +100%
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to –30% H: +20% to +50%
Class 3	10% to 40%	Budget, Authorization or Control	Semi-Detailed Unit Costs with Assembly level Line Items	L: -10% to –20% H: +10% to +30%
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to –15% H: +5% to +20%
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to –10% H: +3% to +15%

Table 3-1: Cost Estimate Classification Matrix for Process Industries

The following are brief discussions of the various estimate characteristics used in the estimate classification matrix (AACE International 1997 & 2003):

Level of Project Definition

This characteristic is based upon percent complete of project definition (roughly corresponding to percent complete of engineering). The level of project definition defines the extent and types of input information available to the estimating process. Such inputs include project scope definition, requirements documents, specifications, project plans, drawings, calculations, lessons from past projects and other information that must be developed to define the project. Each industry will have a typical set of deliverables that are used to support the type of estimates used in that industry. The set of deliverables becomes more definitive and complete as the level of project definition (i.e., project engineering) progresses. However, a careful examination of the level of project definition for each estimate class and its corresponding expected accuracy range does not seem logical. In a Class 1 estimate for example, how can a 50% level of project definition result in a 10% cost underrun on the low side and an overrun of 15% on the high side? In a Class 2 estimate, how can a 30% level of project definition yield a cost underrun of 15% on the low side and an overrun of 20% on the high side? These are typical questions that arise with respect to the level of project definition for each estimate class and its corresponding accuracy range.

End Usage

The various classes of cost estimates prepared for a project typically have different end uses or purposes. As the level of project definition increases, the end usage of an estimate typically progresses from strategic evaluation and feasibility studies to funding authorization and budgets to cost control purposes.

Estimating Methodology

Estimating methodologies fall into two broad categories: stochastic and deterministic. In stochastic methods, the independent variable (s) used in the cost estimating process are generally something other than a direct measure of the units of the item being estimated. The cost estimating relationships used in stochastic methods often are somewhat subject to conjecture. With deterministic methods, the independent variable (s) is more or less a definitive measure of the item being estimated. A deterministic methodology is not subject to significant conjecture. As the level of project definition increases, the estimating methodology tends to progress from stochastic to deterministic methods.

Expected Accuracy Range

Estimate accuracy range is an indication of the degree to which the final cost outcome for a given project will vary from the estimated cost. Accuracy is traditionally expressed as a +/- percentage range around the point estimate after application of contingency, with a stated level of confidence that the actual cost outcome would fall within this range (+/- measures are a useful simplification, given that actual cost outcomes have different frequency distributions for different types of projects). As the level of project definition increases, the expected accuracy of the estimate tends to improve, as indicated by a tighter +/- range. Typical accuracy ranges for Class 1 estimates for example are –3% to –10% on the low side, and +3% to +15% on the high side.

There are in every detailed estimate, opportunities to make mistakes. Errors may include omission of items, under-measurement of quantities, and underestimation of labor requirements. According to Park and Jackson (1984), the actual cost at the end of a project is usually higher than the most precise definitive estimates.

3.6 IMPORTANCE OF AN ACCURATE COST ESTIMATE

The importance of an accurate cost estimate, which is critical to the successful delivery of a project, cannot be overemphasized. Dysert and Elliot (2002) highlight the importance of an accurate estimate from both the owner's and contractor's points of view. From the owner's perspective:

1. If the cost estimate is not accurate, the financial return from the capital investment may not be realized; and compounding this problem is the fact that other deserving projects may not be funded.
2. It helps in establishing the budget for the project.

3. It serves as a tool or resource used for planning, scheduling and cost control.
4. It is used as a yardstick against which the construction budget is monitored during project execution through measurement of progress.

From the contractor's perspective:

1. An accurate estimate is very important because in a stipulated price or unit price contract for example, the profit margin of the contractor is dependent on the accuracy of his or her estimate or unit rates. If the project is exceptionally large, the loss from an inaccurate estimate can potentially put a contractor out of business (bankruptcy).
2. For cost-plus contracts, the contractor will face less direct economic risk from an inaccurate estimate, but the damage to the contractor's reputation can be severe since the client could consider him unreliable and may not be willing to consider him (contractor) for future projects.

3.7 ESTIMATING PITFALLS

No estimator or cost engineer can produce for a project of any significant size or duration a 100% accurate estimate. And if two estimators are given the same information to produce an estimate, it is very likely that they will arrive at different figures depending on each person's approach, skill level, interpretation of design, knowledge of prices, accuracy of cost database, assessment of market conditions and more. And as its name implies, estimating is an approximation procedure that provides answers with significantly less than 100% probability of being correct or even close (Uppal 2003). Although estimates cannot be precise, they must be within acceptable limits of error. Kerzner (1998) has identified some pitfalls associated with estimates, which include, but are not limited to:

- Misinterpretation of the scope of work (Owner or contractor may be liable depending on who is misrepresenting)
- Omissions or improperly defined scope (Owner, liable)
- Poorly defined or overly optimistic schedule (Who is liable depends on who missed items of work)
- Inaccurate work breakdown structure during planning or work packaging (both owner and contractor may be liable)
- Applying improper skill level to tasks during estimating (owner and/or contractor may be liable)
- Failure to account for risks or wrongly accounting for them (owner and/or contractor may be liable)
- Failure to understand or account for cost escalation and inflation (contractor, liable).

Unfortunately, many of these pitfalls do not become evident until detected during the cost control phase, well into the project.

3.8 PROJECT CONTROLS IN CONSTRUCTION PROJECT DELIVERY

Bent and Thumann (1994) define project controls as the process that does the following:

1. Forecasts and evaluates potential hazards prior to occurrence so that preventive action can be taken
2. Reviews trends or actual situations to analyze their impact and, if possible, propose actions to alleviate them
3. Provides constant surveillance of project conditions to effectively and economically create a “no-surprise” condition, apart from force majeure situations.

The end result of an effective project control program is accurate cost and schedule forecasts (re-estimated amounts and durations based on project performance). Project control is carried out by monitoring and measuring progress of work against a baseline (Ward 1992). This baseline is the estimate and an inaccurate estimate would result in a poor project control program. Producing accurate estimates is therefore an imperative for successful project control.

3.9 PREDICTIVE MODELS – INDUSTRY ACHIEVEMENTS

Various prediction models have been developed using primarily historical data or properties. For example:

- A model for predicting performance of Architects and Engineers on Design-Build projects using regression analysis developed by Ling (2002).
- A model for predicting construction contractor failure prior to contract award using regression analysis developed by Russell and Jaselskis (1992).

- A model for predicting design cost overruns on building projects using fuzzy logic developed by Knight and Fayek (2002).

However, the most significant study conducted in relevance to this thesis is the development of a model to predict completed project cost using bidding data (Williams 2002). It is, therefore, briefly discussed. In this study, neural network and regression models have been developed to predict the completed cost of competitively bid highway projects constructed by the New Jersey Department of Transportation using bidding data available at time of bid and the costs (initial bid and final cost) of 302 completed projects. Data studied included the low bid, median bid, standard deviation of the bids, expected project duration and the number of bids. A natural log transformation of the data was found to improve the linear relationship between the low bid and completed cost. This regression model used only the natural log of the low bid as an independent variable to predict the natural log of the completed cost (dependent variable). Neural networks were also constructed to predict the final cost. The best performing regression model produced superior predictions to the best performing neural network model. These models, it is claimed, generally produced good predictions of the completed project cost, but were found to be deficient in predicting very large cost increases. Their inability to predict very large cost increases raises a question on the usefulness of the model.

3.10 PROPOSED THEORETICAL MODEL AND RESEARCH QUESTIONS

The actual construction costs at the end of a project are usually higher than the most precise definitive estimates (Park and Jackson 1984). Although a model to predict completed project cost has been developed using bidding data on public financed highway (low-bid award) construction projects, it fails to predict very large cost increases. In addition, it cannot be used on oil and gas engineering construction projects since the model is limited to highway construction projects in New Jersey. In this regard, the following theoretical model (**figure 3-1**) for final construction cost assessment in the oil and gas industry in Alberta is proposed.

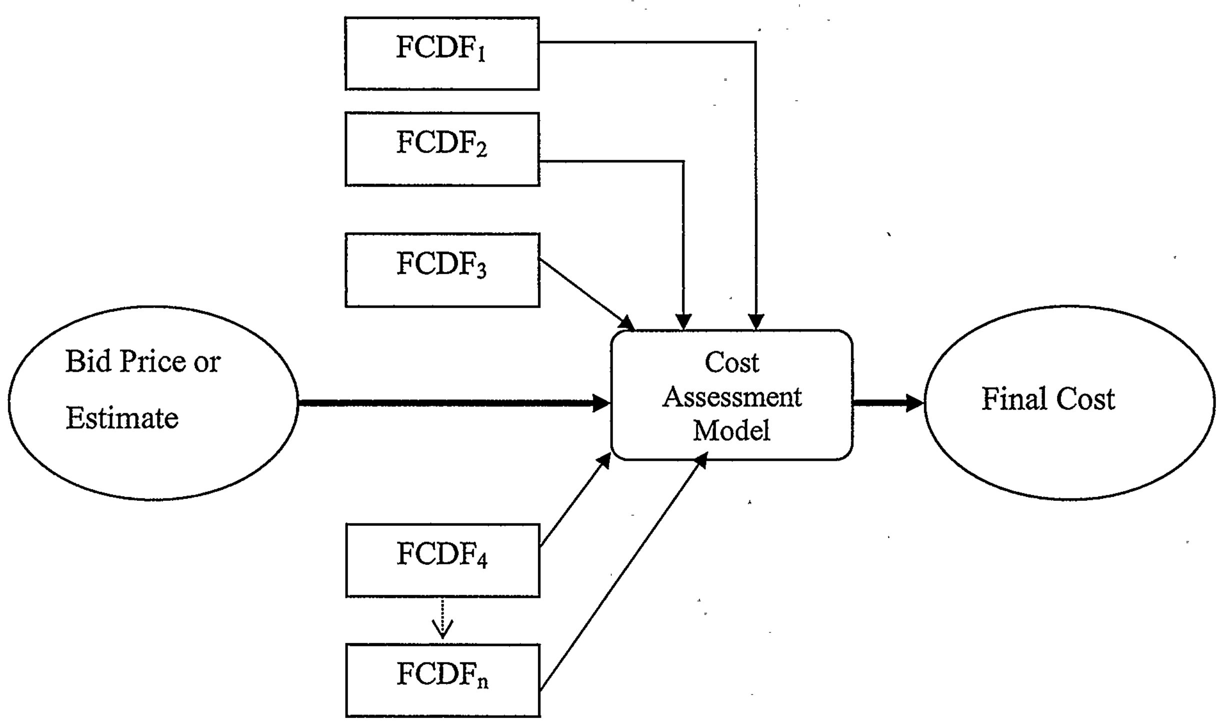

Figure 3-1: Proposed Theoretical Model for Final Cost Assessment

In the above proposed model, bid price or estimate based on unit costs is the primary independent variable and final cost a dependent variable. There are also sub-variables, independent in nature that influence the initial price or estimate in determining the final cost and are labelled $FCDF_n$ – Final Cost Determining Factors; where "n" is the number of factors.

In seeking to develop a mechanism that can assess the difference between bid price (estimate based on unit costs) and the likely final cost of construction, which could help owners and consultants in selecting the most suitable contractor through a modified competitive bidding process, the following research questions were developed for the study:

- Is procuring construction contract services through competitive bidding and other approaches solely about price (raw or adjusted)?
- Is there a significant difference between the low bid price (or estimate based on unit rates) and final construction cost (cost to the owner)?
- What accounts for the difference between bid price (or estimate based on unit rates) and final cost?
- What is the level of impact of each final cost determinant factor on final cost?

The research methods used in collecting data to address these research questions are presented in the next chapter.

CHAPTER FOUR RESEARCH METHODOLOGY

This chapter explains the research methods used in conducting the study. It sets forth reasons for applying the two-phased modified Delphi research data collection approach in narrowing down, and gaining a deeper understanding of' the topic. The modified Delphi method employed in the pilot phase of the study, which basically involved the development of the interview guide, interview implementation and data analysis procedures, are discussed in detail. The chapter also explains the survey design and instrument used in the second phase of the study and the data analysis mechanism employed.

4.1 GENERAL RESEARCH DESIGN

This study was aimed at understanding the contractor and subcontractor selection process in Oil and Gas engineering project construction, the basis upon which construction contracts are awarded, key factors that account for the difference between bid price and final cost to the owner and the impact associated with these factors. Literature indicated that there is usually a difference between the low bid and the final cost of construction to the owner. This was considered applicable to construction in general and no particular sector of the construction industry was singled out. It was therefore necessary to establish whether this applied to the construction of Oil and Gas engineering projects, determine whether the difference is significant and quantify the impact of various factors contributing to the difference through data collection.

The nature of the research necessitated the use of a sequential triangulation method in collecting data in two phases; the pilot and the main phase respectively. Triangulation research methods normally require mixing qualitative and quantitative styles of research and data (Neuman 2003). According to Neuman, mixing the styles can occur in two ways:

- Use the methods sequentially, first one, then the other.
- Carry out the study using the two methods in parallel or both simultaneously.

The concept of triangulation is based on the assumption that any bias inherent in any particular data source, in any particular researcher and in any research approach, will be neutralized when used in conjunction with other data sources, other researchers, and other research approaches (Grinnell 2001; Bogdan & Biklen 1998). Taylor (1997) claims that, to a certain extent, qualitative-quantitative triangulation minimizes the limitation of the quantitative and qualitative methods and can add significant benefits to the issues of validity and reliability. In this respect a two-phase modified Delphi study involving both qualitative and quantitative methods was adopted.

The pilot phase (round one) of the modified Delphi study was carried out with a panel of eighteen experts from the construction industry in Alberta involving personnel from owner organizations, Engineering, Procurement and Construction (EPC) firms, contractors and subcontractors. The pilot phase resulted in the identification of factors that account for the difference between bid price (or estimate based on unit rates) and final construction cost to the owner. In the main phase of the modified Delphi study using a questionnaire, fourteen out of eighteen responses were received representing approximately 78% response rate. The questionnaire was designed to determine the weighting of factors identified during the pilot phase and their impacts.

4.2 SAMPLING DESIGN

The data for a research study can be obtained in one of three ways: from records that already exist; by sampling to obtain new data; or by carrying out an experiment (Manly 1992). Accessing records that already exist would have been the best means of conducting this research but this would have proved futile since the study involves private sector projects and there are no readily available data. This study obviously does not involve experimentation and the researcher was therefore left with the sampling option.

In order to obtain results that would be meaningful, it was necessary to collect data using industry experts representing the population of professionals involved in the delivery of oil and gas engineering construction projects. Since the study seeks to obtain expert professional opinion, the “snowball” sampling approach was used since it is one of the easiest ways to build a pool of participants (Taylor 1997). The strategy of snowball sampling is to locate a few individuals in the population of interest and ask them to identify other people in the same group. These people in turn, are asked to identify still other respondents. The cycle continues until an adequate sample size has been reached (Grinnell 2001). Although this method would hardly lead to representative samples, there are times when it may be the best method available. In this study, selection of the first three participants and their recommendations resulted in a pool of other participants.

In oil and gas engineering construction, there are basically three major players involved:

- Owners (Oil and Gas Companies)
- Consultants (Typically EPC Firms)
- Vendors (Contractors and Subcontractors).

The snowball sampling procedure was controlled in an attempt to include professional experts from all the three categories of players. One senior cost engineer from an EPC firm, who agreed to participate in the pilot phase, refused to sign the consent form and was only prepared to respond to two out of the five questions in the interview guide at the time of interview. His claim for doing so was that some of the questions were of a sensitive nature since he was, at the time, working on a project, which had run into several problems, which he declined to mention. For courtesy reasons, he was interviewed on the two questions without tape-recording but this interview was not included in the analysis. In the end, the pilot phase of the modified Delphi study using the snowball sampling involved a total of 18 participants with an average of 24 years of work experience in the construction industry with a range of 12 to 35 years experience. **Table 4-1** below shows the position of professional experts involved in the pilot phase.

Participant Designation	Frequency By:			Percent	Cumulative Percent
	Owner	EPC	C'tor		
President	1	2	1	22.8	22.8
Senior Vice President		1		5.5	28.3
Vice President	1	2		16.6	44.9
Project Controls Director	1			5.5	50.4
Senior Cost Engineer	1			5.5	55.9
Manager of Risk	1			5.5	61.4
Project Manager	2		1	16.6	78.0
Cost Estimator		1		5.5	83.5
Chief Estimator			1	5.5	89.0
Divisional Manager (Civil Works)			1	5.5	94.5
Construction Manager			1	5.5	100.0

Table 4-1: Position Profile of Interviewees in Pilot Phase

With the exception of one participant who declined to participate in the main phase based on instructions from his superior, all other participants in the pilot phase indicated their willingness to continue participation in subsequent rounds and were therefore sent the main phase questionnaire by electronic mail. One new participant (Project Controls Supervisor with 15 years experience) from the pilot phase referrals also participated in the main phase. Out of a total of 18 participants who were sent the questionnaire, 14 responded. One project manager later declined participation due to work demands and two others (a vice president and a manager of risk) also declined participation with the reason that they will have little justification for their responses if they did participate. One participant (president) failed to respond although contacted by phone and sent reminders by email.

Participants were typically drawn from large (by name and operation) organizations that do the bulk of the work within the Oil and Gas construction industry in Alberta. By a rough count (estimation), there are about 12 large Oil and Gas owner companies, 9 large Engineering, Procurement and Construction (EPC) firms and over 20 construction firms (general contractors and subcontractors being treated as one group as their opinions were invariably the same). Owner participation involved 6 (50%) companies in the pilot phase and 3 (25%) in the main phase. EPC firms participation involved 6 (67%) participants in the pilot phase and 4 (45%) in the main phase. Participation from construction firms involved 5 companies in each phase of the study. The sample size based on participating owner and EPC companies would generally be said to be representative of the population from which they were drawn except for the main phase where owner participation was 25%. There was, however, inadequate representation from general and sub-contracting companies as it was difficult getting them to participate due to their unwillingness to be involved in the study.

Due to the difficulty in getting participation from contractors and subcontractors, saturation for this study was determined by the owner and EPC sample size as a result of the repeated nature of information obtained in the 13 interviews involving owner and EPC companies. Saturation is something that the researcher looks for as an indication that data collection is complete. It means that data collected from new participants simply confirms previously collected data rather than adding new information (Winston 2003). Thus the interview results from the pilot phase were internally verified due to the repeated nature of interviewee (owner and EPC company participant) responses. The sample size of 18 and 14 for the pilot and main phase respectively compares favourably with other Delphi samples indicated by literature. Examples of Delphi sample sizes using a modified approach to the classical method have been as large as 62 participants for a one round and as small as 4 participants for a two round Delphi study (Skulmoski and Hartman 2002).

The factors that account for the difference between initial price and final cost (obtained during the pilot phase) were coded into primary and secondary categories. In phase two, respondents were asked to assign weights to the individual secondary coding category factors as well as the overall weight to the corresponding primary coding category factor (see **table 4-3** under section 4.5 for coding of factors). The average of the individual secondary coding category weights is compared with that of the overall primary coding category weight in verifying the results internally, which are further discussed in the next chapter. The characteristic details of the research samples from the two phases of the modified Delphi process are shown in **table 4-2** below.

SAMPLE COMPARISON	
Pilot Phase	**Main Phase**
• 18 Participants in Total • 7 from Oil and Gas Companies, 6 from Consultancy (Typically EPC), 3 Contractors and 2 Subcontractors	• 14 Respondents in Total • 5 from Oil and Gas Companies, 4 from Consultancy (Typically EPC), 3 Contractors and 2 Subcontractors

Table 4-2: Modified Delphi Sample Comparison

4.3 MODIFIED DELPHI TECHNIQUE

The Delphi method was originally designed to obtain the most reliable computed consensus of opinion of a group of experts by administering a series of questionnaires interspersed with controlled opinion feedback (Linstone and Turoff 1975; Schuster et al. 1985; Helmer 1966). The process can also be used to produce a reasonably accurate forecast when the necessary information to predict an outcome was not available (Hartman & Baldwin 1995). Dalkey (1968) identifies three basic characteristics of the classical Delphi process:

1. Anonymity
2. Iteration with controlled feedback
3. Statistical group response.

The technique attempts to make effective use of informed intuitive judgment and the best that we can do under the circumstances, when we have to rely on expert judgment, is to make the most constructive and systematic use of such opinions (Helmer 1967).

The above (original or classical Delphi) is not the only Delphi format. Delphi is a decision making tool and should be modified to respond to the needs of the individual decision makers (Delbecq et al. 1975). Delbecq et al. claim that some examples of modified Delphi studies have used cassette tapes as a response mode rather than questionnaires. Some Delphi studies stop after the second questionnaire. If a final vote is not needed and clarification is not important, it may be sufficient to feed back to respondents the analysis of the second Delphi questionnaire (Delbecq et al. 1975). In this research, a two-phased modified Delphi approach was used and is further described below.

4.4 PILOT PHASE – EXPERT PANEL INTERVIEWS

The pilot phase of the study was aimed at discovering current procedures and practices in Oil and Gas engineering construction contracting. It was to gather as much information as possible without unduly limiting or directing the responses of interviewees. Five major open-ended questions were developed to serve as an interview guide, and using the opportunity to ask follow-up and probing questions whenever deemed necessary. The interview process involved the interviewer asking questions, listening to responses, taking notes and tape-recording interviewee responses. These open-ended questions, which were pre-tested using two potential participants and revised before being administered to participants, sought to explore current bidding and contracting practices in the Oil and Gas engineering construction sector of the construction industry in Alberta. The interview guide questions were sent to participants three days prior to the interview date by electronic mail. The nature of the questions offered the interviewees the opportunity to freely express their views, thereby reducing researcher bias. Validity in interviews is achieved primarily by having a battle plan specifying the topics to be covered and the kind of information sought, and validity implies reliability (Herzog 1996). Herzog claims that where it is difficult to address the issue of reliability directly such as in unstructured interviews, researchers are likely to focus on providing convincing evidence of validity, confident that reliability may then be assumed. In this regard, these questions covered five major areas:

1. Understanding current selection procedures for construction contractors and subcontractors.
2. The basis on which construction contracts are awarded.
3. Identifying the factors that account for the difference between bid price or estimate based on unit rates and final cost (typically low bid situations).
4. Identifying mechanisms (if any) in industry for assessing the difference between bid price and final cost during bid evaluation prior to contract award.
5. The significance of the study **(See Appendix B for detailed interview guide or questions)**.

One participant responded to the questions by email because of distance and further clarifications were sought by phone. In this case, the researcher had the consent form signed and returned by fax before sending the questions. The interviews were mostly conducted in the offices of interviewees or a place of their choice and were tape-recorded with the agreement of the participants **(See Appendix C for consent form)**. Notes were also taken besides the taping of interviews. In some instances, participants did not consent to the tape-recording since they were uncomfortable with it. Under these circumstances, the researcher explained the purpose of the study, ethical requirements and confidentiality issues in addressing participants' concerns although their request was honored. In the absence of taping, the interviews were conducted at a slower pace, which helped the researcher in capturing all relevant data and gaining an understanding of interviewees' responses. Throughout the interview process, participants were relaxed and helped the researcher in understanding and interpreting their words carefully. The researcher showed interest in participant responses and encouraged elaboration, thus creating a dynamic interview environment. In general, both the researcher and interviewee jointly controlled the pace of each interview. In dealing with vital interview questions, the researcher often rephrased the interviewee's response in seeking confirmation and/or clarification. In situations involving the use of numerical values, interviewees were asked to provide documentary evidence in support of given examples which are further discussed in chapter five of this thesis.

Through the interview guide and follow-up questions, the researcher gathered vital information relating to construction contracting procedures in Oil and Gas engineering construction. Responses from the pilot phase served as the basis for formulating the main phase questionnaire.

4.5 DATA ANALYSIS PROCEDURES – PILOT PHASE

The qualitative data obtained from the pilot phase interviews using the modified Delphi technique was collected systematically and analyzed consistently. Most interviews, which were tape-recorded with the consent of participants, were transcribed word for word into a Microsoft Word document. During the analysis, the researcher searched for patterns in the collected data. The idea of Neuman (2003) in qualitative data analysis was employed in organizing the raw data into conceptual categories and creating themes or concepts. In order to achieve this, the researcher summarized the raw data from transcripts and notes for each participant in a bullet form. From this, common terms, events and themes were highlighted. This made it easy to link common themes and concepts together.

Coding categories for factors that account for the difference between bid price (or estimate based on unit rates) and final cost were also created. Coding data is the hard work of reducing mountains of raw data into manageable piles (Neuman 2003). One of the objectives in the pilot study was to identify key factors to be considered in developing a final cost assessment model. Factors were classified into primary and secondary coding categories, thereby enabling the researcher to identify the codes more quickly. The primary coding categories represented the fundamental concepts and opinions of participants.

The analysis was organized and condensed in order to provide respondents with feedback, reduce their time in responding to the questionnaire and to further arouse their interest in participating in subsequent rounds. **Table 4-3** is a presentation of the entire sample coding categories.

Primary Coding Category	Secondary Coding Category
Change Orders	• Number & magnitude of changes • Change order administration/management • Changes in work condition or situation • Variations in quantity
Level of Scope Definition	• Design or engineering completeness • Differences in opinion as to scope • Change in scope of work • How well responsibilities are defined • Thoroughness of risk analysis on design • Inconsistent documentation (quality of bid package) • Right contractual terms
Bid	• Time to Bid • Clarity of request for bids • Mistakes in contractor's or subcontractor's bid • Omissions by bidder • Completeness of bid package • Thoroughness of pre-award interview • Bid clarification
Contract Risks	• Higher contract administration costs • Litigious nature of Owner (Buyer) • Litigious nature of Contractor or Subcontractor • Litigious nature of Designer (Consultant)
Market Conditions	• Change in wage rates • Change in material prices • Quality and availability of workforce

Primary Coding Category	Secondary Coding category
Risk Management Issues	• Job location • Contractor's construction management expertise • Owner's construction management expertise • Risk allocation to the right party • Whether bidder has assessed the difficulty of the work correctly or not
Performance	• Rework (due to quality by contractor or subcontractor) • Rework due to late changes by owner or designer • Failing to meet specifications due to interpretation differences • Owner's influence on contractor or subcontractor (schedule effect) • Effect of site productivity • Field supervision costs

Table 4-3: Data Coding Categories of All Cost factors

4.6 MAIN PHASE - QUESTIONNAIRE

In the main phase of the study, a brief summary of the pilot phase interview results were presented as feedback to the participants. Questions for this phase were developed based on the results of the pilot phase and guided by the literature review. The main phase questionnaire was also pre-tested twice and revised before being administered to participants. The objectives of this phase of the study were to:

- Determine how critical each factor identified in the pilot phase was on final cost by assigning weights on a 7-point Likert scale.

- Identify the critical factors that account for the difference between bid price (for stipulated price contracts) or estimate based on unit rates (for cost plus and unit price contracts) and the final cost of construction through percentage impact assessment under perfect (optimal conditions or when conditions are favorable), likely (typical conditions expected on everyday project delivery) and outrageous (when there is a badly mess up and everything else goes wrong) conditions.

These key factors were synthesized based on the analysis of the interview transcripts and notes. The participants were asked to add other factors deemed necessary and assign a weight to each factor based on how critical a factor might influence final cost. This was done using a Likert scale where: (1=not at all critical, 2=not critical, 3=somewhat not critical, 4=neutral, 5=somewhat critical, 6=critical, 7=very critical).

In estimating the percentage impact of each factor on the probable final cost of construction per contract type under Perfect (P), Likely (L) and Outrageous (O) conditions, the definition of each condition was provided using two sources of reference: Ahuja et al. (1994) and Hartman (2000).

Thus these questions in general were aimed at cross-verifying opinions among respondents regarding cost impact assessments **(See Appendix D for main phase questionnaire)**.

4.7 STATISTICAL ANALYSIS OF QUANTITATIVE DATA – MAIN PHASE

In the main phase of the Delphi study, quantitative data were collected through a survey and statistical functions in a Microsoft Excel™ program were used to analyze the quantitative data in order to determine the statistical significance of the results. For a more efficient statistical analysis of the data, measurements were classified into two categories: ordinal and ratio measurements respectively.

4.7.1 Ordinal Measurements

Ordinal measurement involves an underlying continuum in which the numerical values are ordered so that small numbers refer to lower levels on the continuum, and large numbers to higher points; however, the distances between the assigned numbers and the underlying continuum are not in a one-to-one relation with each other (Jackson 2003). In questions of the survey, assigning a weight to each factor on a scale of 1 to 7 was an ordinal measurement with the bigger number "7" indicating very critical and the smallest number "1" indicating not at all critical. However, we do not know that the distances between the values are equal: the distance between 3 and 4 on the scale may not be the same as the distance between 6 and 7. Ordinal measurement orders values but does not assure equal gaps between the measurement points (Jackson 2003).

4.7.2 Ratio Measurement

The percentage impact assessment of each factor per contract type is a form of ratio measurement. With ratio measurement, the zero point is aligned with true zero and the distances between the intervals are equal (Herzog 1996 and Jackson 2003). For example, the percentage impact assessment on the factor "number and magnitude of change orders" is a variable whose nature makes it possible to be represented with a single percentage numerical value. In this case, it is also possible to use zero percent (0%) to reflect no impact on final cost and other percent numerical values to reflect all other levels of impact. In ratio measurement, it will be correct to say that an impact of say 150% is thrice as much as an impact of 50%. It is possible with ratio type of measurements to add and subtract constants as well as to multiply or to divide by them without changing the proportionality among the values.

4.7.3 Descriptive Statistical Indicators

For both ordinal and ratio measurements, descriptive statistical analysis was used. The various descriptive statistical indicators used in the analysis are briefly described below (Anderson et al.1999, Hines et al. 2003):

- **Mean:** The mean provides a measure of central location for a data set, which in this study reflects the average opinion of respondents.
- **Median:** The median is the score found at the exact middle of the set of values when the data items are arranged in ascending order. If there is an odd number of items, the median is the value of the middle item. If there is

an even number of items, the median is the average of the values for the middle two items.

- **Percentile:** The p^{th} percentile is a value such that at least "p" percent of the items take this value or less and at least (100-p) percent of the items take this value or more.
- **Range:** The range indicates the gap between the lowest and highest value in a sample. It is computed by subtracting the lowest value from the highest one and represents the spread in opinion of all respondents.
- **Variance:** This is a measure of variability that utilizes all the data values. It is based on the squared distances between the values of the individual scores and the mean divided by the sample size (n) minus 1. The squared units associated with variance make it difficult to obtain an intuitive understanding and interpretation of the numerical value of the variance. Hence, it is more useful in comparing the amount of variability in two or more data sets. In a comparison of data sets, the one with the larger variance has the most variability and furthermore, the interpretation of the values of the variance may not be necessary.
- **Standard Deviation:** The standard deviation (SD) is one of the several indices of variability that are used in statistics to characterize the dispersion among the measures in a given sample or population. It tells how tightly clustered a set of values is around the average of those same values. It is a measure of dispersal, or variation in a group of numbers. If a set of numbers is close to the average of those values, then we may

expect to see a low SD. In contrast, if the set of numbers is spread across a greater range, it may present a high SD. Higher SD is often interpreted as higher volatility and a lower SD an indicator of stability. The most consistent values will usually be the set of values with the lowest SD.

- **Coefficient of Variation:** It expresses the standard deviation as a percentage of the mean value. Just like variance, it is useful in comparing the variability of different variables. It is computed by dividing the standard deviation by the absolute value of the mean and multiplying by 100.
- **Skewness:** This is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point (median). The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Negative values for the skewness indicate data that are skewed left and positive values for skewness indicate data that are skewed right. Skewed left for example means that the left tail is heavier than the right tail..

Appendix E, F and **G** shows some of the results of the descriptive statistical analysis, which are discussed in detail under results and discussion in Chapter 5.

CHAPTER FIVE RESULTS AND DISCUSSION

This chapter presents the results and analysis derived from the information and data obtained from the two-phased modified Delphi Study. These results form an integrated part of the overall results including the review and the development of research methods.

5.1 PILOT PHASE RESULTS – MODIFIED DELPHI METHOD

5.1.1 Current Vendor Selection Methods – A General Overview

Competitive bidding (discussed further in section 5.1.2) was discovered as the most common method by which vendors (contractors and subcontractors) are selected for Oil and Gas engineering construction work in Alberta, Canada. This affirms the view expressed by Silberman (1993) and Clough (1981) that most contractors obtain their work through price competition. Vendors, to a lesser extent are selected through nomination by owners or their agents (typically EPC or EPCM firms) with whom they have long-term working relationships such as alliances or partnership agreements. Here, the terms and conditions of the contract are arrived at through negotiation. A specialized contractor (sole source) may sometimes be asked to submit a bid or proposal where the final contract is also reached through negotiation. Another situation that necessitates contract negotiation is where a pre-qualification process may result in a short list of only one vendor because only one vendor meets the pre-qualification criteria. These limited cases of using negotiation (average, 20% of cases) remain the owner's prerogative or that of his authorized agents.

One interesting observation with respect to competitive bidding was the confirmation of two of the three bidder types described by Crowly and Hancher (1995) in chapter three - phantom, mistaken and fair bidders. This was confirmed in what four respondents described as industry bidding philosophies. It was said there are two principal bidding philosophies in use in the construction industry:

1. Bidding low just for purposes of winning the contract and recovering losses through the playing of games during the execution of the project.
2. Submitting a realistic bid and taking chances to either win or lose.

In one particular interview, the interviewee (Contractor) said he was due to submit a bid a few hours after the interview and that he was aiming at being the low bidder since the job will be strictly awarded to the lowest bidder. When asked how he would ensure getting some profit, he responded that profit was not a consideration at that stage. What was important is getting the job and playing games later on, since he had detected some inconsistencies in drawings and specifications which he was counting on to result in the issue of change orders.

5.1.2 Vendor Selection – The Competitive Bidding Process

The competitive bidding process (illustrated in **figure 5–1**) is usually done as part of a due diligence process by owners or their authorized agents in selecting vendors. In this process, the owner or his agent, such as the EPC or EPCM firm, acts as the bid organizer who manages the bidding process and the bidders act as competitors. The key considerations and procedures typically followed in the competitive bidding process are briefly discussed below:

1. The first step in the competitive bidding process is pre-screening of prospective bidders. Some companies keep a long-standing list of potential bidders over time, which may be obtained through applications submitted by bidders for inclusion in the company's long list of vendors. Applicants are sent a questionnaire asking them for their financial capability, whether they are union or non-union, how many people they employ, what type of work they do, what their safety program is, and so on. Responses to the questionnaire are scored and vendors must obtain a minimum score in order to be included in the long list. References of these applicants are sometimes checked for basic information such as success on projects executed for clients and litigation history since no client would want to work with a litigious bidder. When clients or their agents have satisfied themselves with the information provided and/or references obtained, then the prospective bidders are included in the long list. Another alternative is where bid organizers keep what they call a "corporate bidders" list. This is a list of contractors and subcontractors with whom bid organizers have had a good prior working experience. The problem with this approach is that it excludes new competition.

2. Prospective bidders on the long list are then invited to submit pre-qualification bids. At this stage, the successfully pre-qualified bidders are included in a short list that would be formally invited to submit bids or unit rates. Pre-qualification information requested, against which evaluation is carried out in determining the short list, includes but is not limited to safety record, current workload, availability of personnel, record of previous projects executed (containing information on nature of project, contract price, project duration etc. in order to determine the contractor's capability in executing the current project if selected for contract award), geographic location of project relative to contractor, financial and bonding capacity, union affiliations, equipment holding and more. The safety record furnished by potential bidders from the workers compensation board is generally given a heavier weighting during evaluation in comparison to other factors. In some organizations, a prospective bidder's inability to pass the safety hurdle, regardless of how many points he scores would not be enlisted to submit a bid. One exception to the formal pre-screening and pre-qualification process discovered during the interviews, is the situation where preferred contractors or subcontractors are directly invited to submit bids without having to go through pre-screening or pre-qualification.
3. After a formal request for the submission of bids (typically, sealed bids) has been made and bids received, they are checked for compliance and evaluated against a set of pre-established technical and commercial

evaluation criteria usually disclosed in the invitation to bid. Bid prices could be adjusted where the bid contract allows for it, and this is discussed further in subsequent sections of this chapter. The result of the evaluation process is the recommendation of a successful bidder for contract award.

4. Prior to contract award, a pre-award meeting is sometimes conducted with the recommended bidder. This is usually done where clarifications are necessary or where the need arises for contract negotiation.

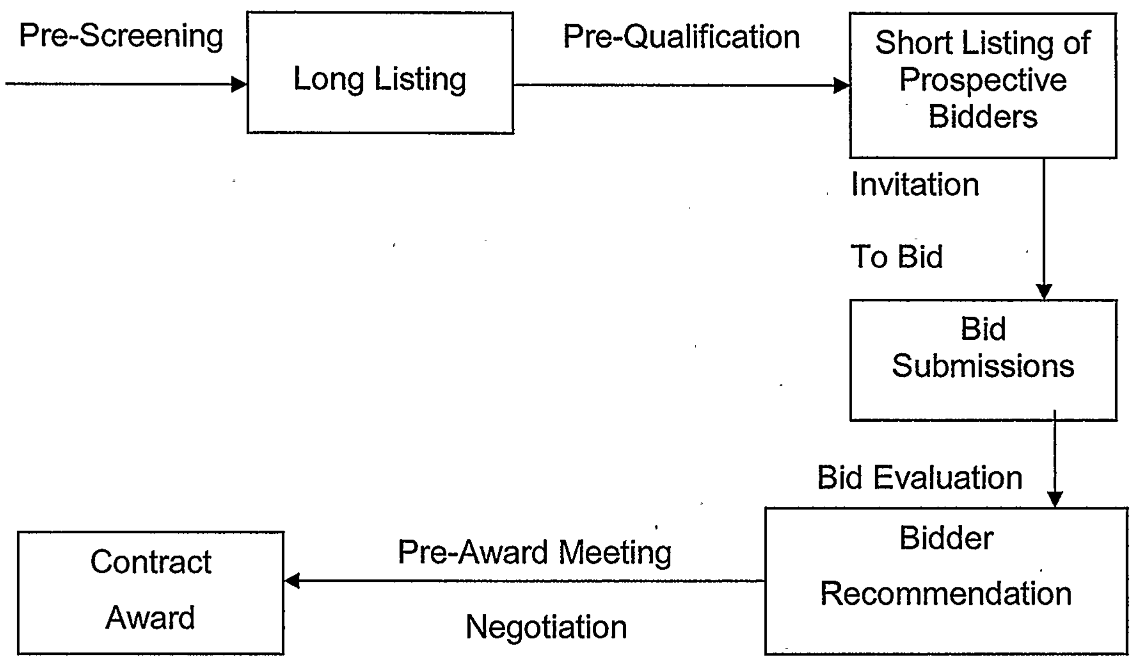

Figure 5-1: Competitive Bidding Process in Oil & Gas Eng. Construction

5.1.2.1 Basis of Contract Awards

There are basically three different opinions regarding which contractor or subcontractor is awarded the construction contract.

One out of the eighteen participants, a Project Controls Director (PCD) stated that price is not an issue when it comes to bidder selection. Rather, the award is made to a bidder with the best cultural fit to that of their own organization (client). It is interesting however, to note that another participant (Vice President), from the same organization as the PCD, presented a different viewpoint: that they would generally pick the lowest technically compliant bid. This difference in opinion was not further investigated due to the obvious problems it might create.

Nine out of the eighteen participants (50% of respondents) stated that contract awards are made to the lowest technically compliant bidder. For stipulated price contracts, the award is made to the bidder with the lowest price offer. For unit rate contracts, the award is made to the bidder who submits the lowest lump sum price. This lump sum price is obtained by summing the extension of the unit quantities and their corresponding unit rates. Certain cost plus contracts are awarded based on estimated quantities against which labor rates and/or fees are applied. From this, the overall lowest price offer based on rates and fees will be selected. Other cost plus contracts are awarded based on some performance measures guided by the owner's construction budget. It was argued that since the bidders have been pre-qualified, they are comparable in performance capability. It was further said that, if one is not prepared to award to a particular bidder, then he should not even be short-listed, let alone invited to submit a quotation. Once invited, due diligence process (Canadian practice as defined by the Ron Engineering case) requires the lowest bidder to sign the construction contract except where other criteria are explicitly used for selection. Two respondents expressed the view that price is given a heavier weighting (about 70%) and the remaining 30% spread among other predetermined factors such as quality, schedule etc. One participant expressed the view that the lowest bidder, who was within +/- 10% of the engineers estimate, wins the contract.

Five respondents expressed the view that the award is made to the overall best bidder. Best bid was defined as one with the best people, schedule, price, quality program, safety program and other pre-established factors. A typical illustration of the best bid scenario involving two bidders "A" and "B" is found in **table 5-1** below.

Best Bid Factor	**Bidder A**	**Bidder B**
Raw Bid Price	$11,000,000	$10, 500, 000
Schedule	Best ($0)	Worst ($500,000)
Quality	Worst (Say 400,000)	Best ($0)
Safety	Best ($0)	Worst (Say $500,000)
Changes	Best ($0)	Worst ($200,000)
ADJUSTED BID PRICE	**$11,400,000**	**$11,700,000**

Table 5-1: Best Bid or Lowest Adjusted bid Price Selection Method

From the above table, making a choice based on the raw bid price submitted by each bidder will result in the selection of bidder "B" with the lowest bid of $10.5 million. The adjustments may be made as follows:

- If schedule advantage is worth $100,000 per day and bidder "A" is 5 days better in schedule than "B", bidder "A" would have a total cost saving of $500,000 to the client. This amount is therefore charged to the raw bid price of "B" in adjusting his initial price offer. This does not, however, take into consideration the likelihood of contractor "A" meeting their proposed schedule.
- Bidder "A" from say past experience does not do as good a quality job as compared to "B". The amount of additional supervision the client would have to do in the getting him to produce the right quality is assessed (say $400,000) and added to his raw bid price.
- Safety record shows that bidder "B" will need further supervision in order for him to give the client the best safety job which could cost the client say $500,000.
- From past experience, "B" gives the client the most changes on reasonable scope and that may cost the client, based on his judgment an additional $200,000.

In this example, "A" with the lowest adjusted bid price of $11.4 million is judged the best bid. Unit price and cost plus contracts are adjusted using the same procedure. In this case, it will be the overall best or lowest adjusted rate. Some subcontractors who are familiar with this adjustment process complained that it is done arbitrarily and for which reason they are usually not selected for the award.

5.1.3 Accounting for Differences between Initial Price and Final Cost

Seventeen of eighteen (about 95%) respondents agreed that the low bid system of contract award is the most commonly accepted while one said price is only one factor that receives a heavy weighting. On the question of whether there is a significant difference between the low bid and the final cost to the owner, the responses are classified and discussed as follows:

- 8 respondents said the difference could be potentially higher than the initial price.
- 6 said there is a significant difference.

Exactly one out of eighteen said the following:

- Growth in cost is never zero and that the difference could be low, high or medium.
- "No", unless the low bid contained errors of some sort that would translate into an expectation of higher costs for the owner.
- There is usually not much difference from a subcontract perspective.
- There is certainly a difference but the final cost gets larger as the project gets bigger.

These responses present adequate evidence that there is a difference between initial price and final cost. And 14 respondents overall said the difference is, or could be, significant. In view of the above responses, respondents gave the factors that could account for the difference between initial price and final cost to the owner. These were coded into primary and secondary categories as shown in **table 4-3** in Chapter 4 of this thesis.

The pilot phase of the study also investigated whether there was a mechanism by which industry practitioners are able to assess the difference between initial price and final cost. Responses varied as follows:

- Eleven responded that they had no formal process of assessing the difference. However, they claimed they attempt to do so by allowing for growth in the selected contractor's bid based on the owner's internal estimate, experience, historical data and personal judgment. Growth allowances cited varied from 10% to 60%. One respondent for example stated that, typically, the final cost has been in the range of 105 to 115% of the bid value regardless of whether the bid was awarded to the lowest bidder or some other criteria were used. And that in non-typical sub-contract situations, the final cost has been as high as 200% of the initial bid value.
- Two responded that they are able to determine the difference through risk analysis and judgment. Of this, one said that the final cost generally comes in under their (Contractor) budget where they make awards to sub-contractors.

- One participant responded they had no way of determining the difference and that the final cost depends on what is built and not what is designed and tendered.
- Four participants (2 contractors and 2 subcontractors) responded that they had no way of knowing what the final cost would be and were not aware of any of their clients who were capable of assessing a final cost.

The researcher asked for documentation of some recently completed projects showing the initial price and the final cost; especially from those who were interviewed in their own offices and who claimed they finish at the contract price or finish under budget. Typical responses to this request were:

- Company policy does not allow that.
- It is proprietary information.
- Instructed by superior officer not to disclose any company information.

The interpretation of these responses could be one of three things. It may truly be proprietary information or there is no documentation or the respondent may be embarrassed as a result of providing the evidence. One respondent who did so by electronic mail attached a bid analysis report in which 7 out of the 13 projects were awarded to the lowest bidders. Cost overruns for all the 13 projects ranged from 1% to 41%. These were small projects up to about 3 million dollars. Not much could be derived from these data since they are from only one source.

5.1.4 Importance of Final Cost Assessment

Some respondents indicated the importance of a mechanism that could be developed that assesses final cost at time of bid and these reasons are presented as follows:

- There will be few or no surprises on projects.
- It would enable clients to know their total cost commitment to projects at time of award. This will preclude the need for additional sourcing of funds when projects have reached advanced stages.
- Substantial amounts allocated to possible future increases in existing contracts can be used for other purposes.
- It would prevent many of the embarrassments to both clients and consultants.
- Contract cost overruns will be reduced to a minimum.

5.2 MAIN PHASE RESULTS

The assignment of weights and impacts (%) to factors that account for the difference between bid price or estimate based on unit rates and final cost of construction to the owner was carried out by respondents with respect to the three basic types of contracts – stipulated price, unit price and cost plus contracts. It was realized during data analysis that most of the secondary category factors under each primary category were not truly independent and had some overlaps. These overlaps are dealt with in section 5.2.1 below.

5.2.1 Dealing with Factor Overlaps

The Venn diagram below for example shows the overlaps in "change orders".

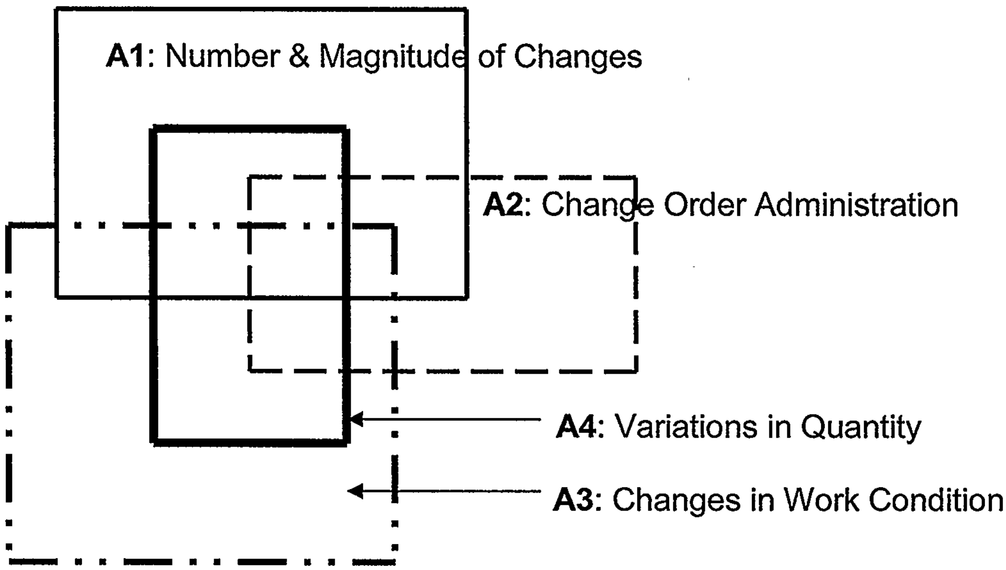

Figure 5-2: Change Order Overlaps

The number and magnitude of changes (A1) would influence change order administration cost (A2); the greater A1, the higher will be A2 and vice versa. The percentage cost of administration for a $100 change is much bigger than for a $100,000 change. Changes in work condition A3 impacts A1, A2 and A4. Furthermore, A4 impacts A1 and A2. Summing A1 to A4 would therefore represent an exaggeration of the total impact associated with change orders since they are not truly independent variables. The extent of overlap is not known. As an approximation, the four factors (A1 to A4) are treated as a single group. In dealing with the change order overlaps, A1 to A4 are (for analysis purposes) averaged for each PLO (perfect, likely and outrageous) condition per contract type. The same procedure was used in arriving at the total impact associated with all the other primary category factors (**Appendix H**) with the exception of "Market Conditions" where E2 (change in material prices) is truly independent of E1 (change in wage rates) and E3 (quality and availability of work force). Since E1 depends on E3, both are averaged and added to E2 in obtaining the total impact associated with market conditions.

5.2.2 Monte Carlo Simulation – A General Overview

Monte Carlo simulation was used in determining the potential cost overruns (explained under section 5.2.3) per contract type. By definition, this is "the use of random sampling to estimate the output of an experiment" (Taha 1997). A typical algorithm for a Monte Carlo simulation consists of the following steps (Ahuja et al. 1994):

1. Generate a uniform random number on the interval 0-1 for each independent variable in the system
2. Transform the random number into an appropriate statistical distribution, the resulting number is referred to as a random variate
3. Substitute the random variate into the appropriate variable, compute the desired output parameters within the model and store the resulting output for further statistical analysis
4. Repeat steps 1-3 a large number of times (the generated uniform random numbers must be different in each iteration)
5. Analyze the collected sample of output.

Generating random numbers is easily done by a computer. Ahuja et al. (1994) stated that "a random number generator should produce fairly uniform numbers on the range [0, 1] which appear to be independently sampled, dense enough on the interval [0, 1], and reproducible".

Generating a variate from a random number is a process of transforming the random number to a point in the cumulative distribution curve and random variates can be generated for various probability distributions. Decisioneering Inc. (2002) in a Crystal Ball simulation reference card describes 17 distributions and conditions for their use.

The simulation outcome is a function of the values of the parameters of the system elements. Simulation should produce statistical results that allow the user to understand the behaviour of the system being modeled under various input parameters. When input parameters are represented as probability distributions, the simulation program generates random numbers that are translated by the simulation program into appropriate random variates, and collects the results to produce a statistical analysis. As a result of the statistical analysis the user would know for example, the minimum, the maximum, the mean, the standard deviation etc. of the sample data outputs. The user will also get the cumulative density function (CDF) curve. By analyzing the CDF curve, the user is able to know the probability associated with any output and the output associated with any probability.

5.2.3 Simulating the Cost Impact (PLO) Data

For each of the 7 parameters or factors (Change Order, Level of Scope Definition, Bid, Contract Risks, Market Conditions, Risk Management and Performance) in a single simulation scenario:

1. A random number was generated in a Microsoft Excel spreadsheet
2. The random number was transformed into a random variate using a triangular distribution and by definition, a triangular distribution is one in which the minimum and maximum data values are fixed with a most likely value in this range, which forms a triangle with the minimum and maximum values (Decisioneering Inc. 2002)).

The random variate (output) for the 7 independent sources of randomness are added together in arriving at the total cost overrun, which if added to the initial (planned) estimate will result in the final cost of construction. The term "overrun" refers to the amount by which actual cost exceeds planned (estimated) cost (Ahuja et al. 1994). A 0% overrun for example, means actual cost equals estimated cost and a 100% overrun means actual cost exceeds estimated cost by 100%.

Discovering the overlap in factors after data collection, the secondary final cost determining factors under each primary factor (see **table 4-3**) were typically averaged to obtain the overall total impact for the primary factors. Each secondary factor was categorized based on its origin relative to the primary factor. For example, the secondary factors such as clarity of request for bids, time to bid, etc. are sub-factors originating from the bid process. In this way, it would be reasonable to treat the primary final cost determining factors as independent variables.

The results of the simulation are later presented and discussed under each contract type.

5.2.4 Definition of Abbreviations

The analysis for the various types of contracts is discussed below and the following abbreviations are used:

MAW – Mean Assessed Weighting: This is the average of the overall weightings assigned to a primary category factor such as change orders, level of scope definition etc. by respondents (**see Appendix E, F and G**).

MCW – Mean Computed Weighting: This is the average of all secondary category factors under a primary category.

PD – The percentage difference between MAW and MCW, which is computed by the formula [(MAW-MCW)/MAW] x100%

5.2.5 Stipulated Price Contracts

5.2.5.1 Weighting and Impact Analysis

Tables 5-2 below shows the results on the assignment of weights and impacts by the respondents, which are discussed together with the data in **Appendix E.**

Primary Cost Factor	Weighting			Overall Impact (%)		
	MAW	MCW	PD	P	L	O
Change Orders	6.25	5.79	7	-1.82	10.05	83.54
Level of Scope Definition	6.25	5.43	13	0.03	11.76	52.74
Bid	5.75	5.31	8	-1.02	6.96	33.31
Contract Risks	5.63	5.40	4	-0.35	5.69	67.69
Market Conditions	5.75	5.15	10	0.54	9.95	65.76
Risk Management Issues	5.25	5.57	6	-1.58	6.42	40.65
Performance	5.50	5.44	1	0.48	7.35	36.72

Table 5-2: Overall Weights and Impacts for a Stipulated Price Contract

The P, L & O values in **table 5-2** above are average cost impact figures per cost factor and similar tables for unit price and cost plus contracts are derived in the same way.

Generally, there were small standard deviations (in the range of 0.80 to 2.00) associated with the weightings for both the primary and secondary cost factors as seen in **Appendix E**. This indicates that there was not much variation in responses with respect to the assignment of weights by respondents. There is not much variation between the MAW and the MCW as shown in **table 5-2** by the percentage difference between the two. This is a verification of the internal consistency in the assignment of weightings by respondents. It can therefore be said that there was an agreement on the degree to which a factor could influence final cost. The average of the overall mean assessed weightings reveal that the level of influence, using the primary coding category final cost factors, approximately ranges from “somewhat critical” to “very critical”.

The percentage impact assessment of the secondary coding category cost factors as seen in **Appendix E** indicates a wide diversity in opinion due to the relatively large standard deviations (in the range of 1.55 to 133.13). The range of standard deviations under perfect, likely and outrageous conditions are 1.55-9.94, 3.50-17.76 and17.82-133.15 respectively. Hence the computed overall impacts as shown in **table 5-2** above for the primary cost factors will also represent a wide range of professional opinion under each condition. There was however no justification for further statistics because of the small sample size, which may not be generalizeable.

5.2.5.2 Overall Cost Overrun Determination – Monte Carlo Simulation

In determining the potential final cost change for stipulated price contracts, the PLO data values in **table 5-2** were simulated (1,000 iterations) using a Microsoft Excel program. The result of this simulation is presented in **figure 5-3** and **table 5-3.**

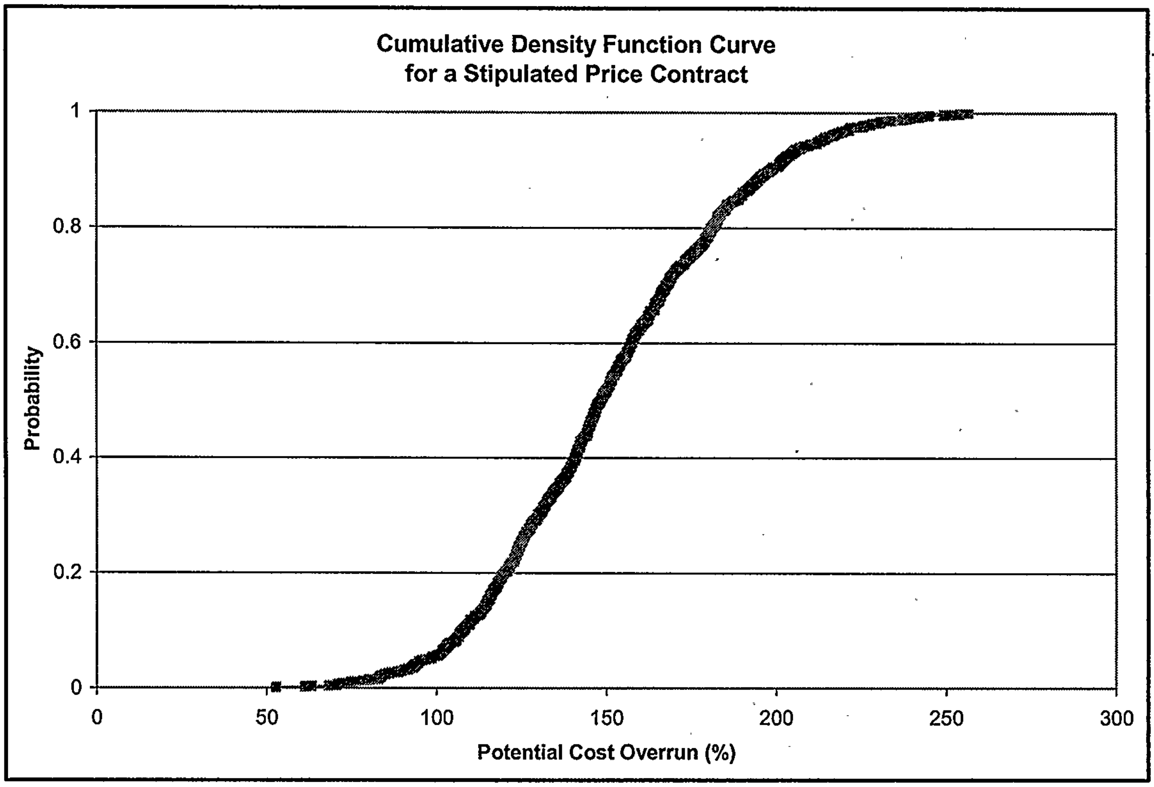

Figure 5-3: Potential Cost Overrun as a percentage of Initial Bid Price

Statistic	Value
Minimum	52.75
Maximum	256.64
Mean	151.01
Standard Deviation	35.10
Coefficient of Variation	23.25%

Percentile	Value
5^{th}	98.05
10^{th}	107.80
20^{th}	120.01
30^{th}	130.05
40^{th}	140.87
50^{th} (Median)	148.54
60^{th}	157.59
70^{th}	168.13
80^{th}	181.37
90^{th}	198.05
95^{th}	212.98

Table 5-3: Potential Cost Overrun Statistics for a Stipulated Price Contract

From **figure 5-3** and **table 5-3**, the mean potential cost impact is about 151%. The minimum and the maximum values are indications that there is a wide dispersion of the data points in the range of about 53% to about 257%. Using the percentile statistics, the 5th percentile with a value of 98.05% for example, means the probability that cost overrun is less than or equal to 98.05% is 0.05 and the probability that the overrun is greater than or equal to this value is 0.95. The CDF curve is skewed to the right (positive skew), which is an indication that the data points tend to lean more towards cost overrun than savings.

The cost overrun simulation output per factor was expressed as a percentage of the total output resulting in the pie chart in **figure 5-4** below.

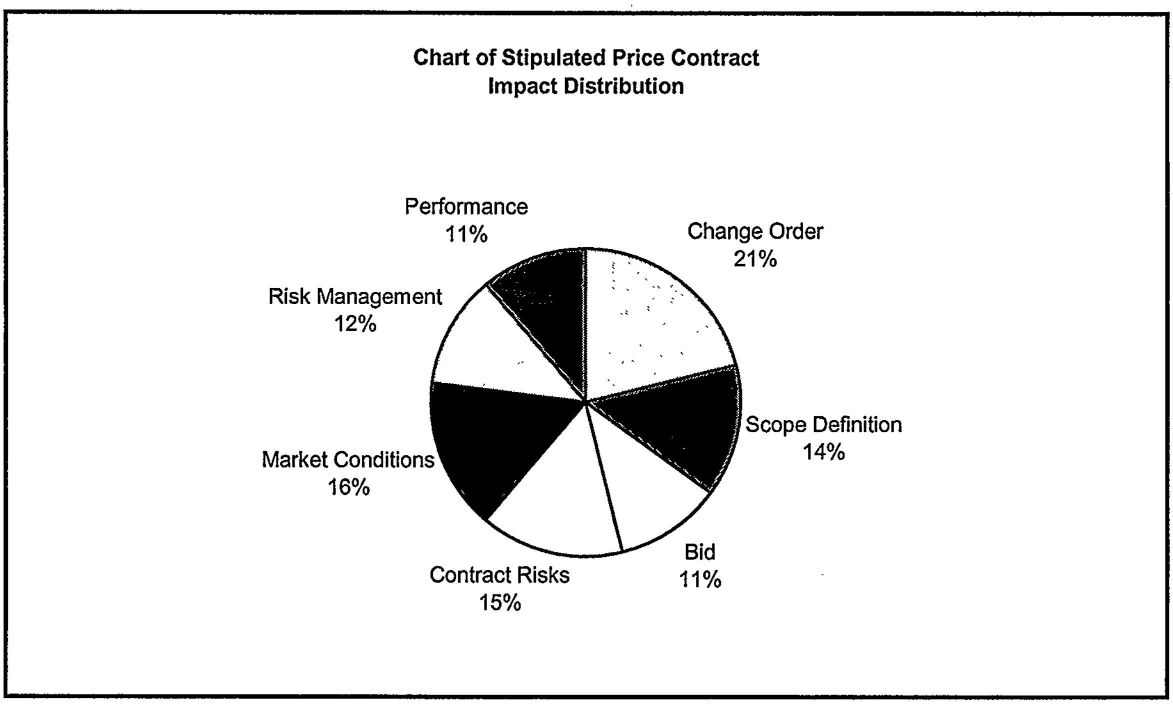

Figure 5-4: Cost Factor Impact as a Function of a Stipulated Price Contract

Figure 5-4 shows the various contributions per cost factor as a percentage of the total overrun for a stipulated price contract with "Change Orders" having the highest (21%) contribution. The "Bid" and "Performance" factors each has the lowest contribution of 11%. How some of the cost impacts for each factor change as a function of contract type is inconsistent with the results of the weightings. For example, "Change Order" and "Level of Scope Definition" with a MAW of 6.25 each has significantly different contributions of 21% and 14% respectively to the total cost overrun. This inconsistency is, however, not surprising since there is so much variability associated with the cost impacts as opposed to the variability associated with the weightings. The reason for introducing the weightings was to do a comparison with the impacts to ensure internal validity of the data. However, due to the magnitude of the variability associated with the cost impact data, it would be inappropriate to compare the weightings to the impacts.

The class of estimate which matches a stipulated price contract according to the cost estimate classification matrix (AACE International 2003) for process industries is the check or bid estimate (Class 1 estimate). This estimate category with its associated accuracy range should result in a final cost of –3% to –10% on the low side (cost savings) and +3% to +15% on the high side (cost overrun). The statistical result presented in **table 5-3** indicates an average cost increase in the range of about 53% to about 257%, which are significantly higher than the estimated accuracy range of a typical Class 1 estimate.

5.2.6 Unit Price Contracts

5.2.6.1 Weighting and Impact Analysis

The analysis of weightings and impacts as presented in **Appendix F** are discussed together with the overall results shown in **table 5-4** below.

Primary Cost Factor	Weighting			Overall Impact (%)		
	MAW	**MCW**	**PD**	**P**	**L**	**O**
Change Orders	6.28	5.77	8	-1.88	9.44	80.74
Level of Scope Definition	6.71	5.70	15	-2.39	8.93	58.28
Bid	5.38	5.31	1	-0.75	5.04	24.51
Contract Risks	5.38	5.54	3	1.53	5.35	30.50
Market Conditions	5.38	5.43	1	2.00	13.10	68.30
Risk Management Issues	5.75	5.11	8	-1.19	4.67	31.46
Performance	5.63	6.09	8	1.98	8.35	34.23

Table 5-4: Overall Weights and Impacts for a Unit Price Contract

The standard deviations associated with the weighted cost factors as shown in **Appendix F** are relatively low in the range of 0.48 to 3.08. This implies that there was agreement on how much influence these factors have on final cost. From **table 5-4** above, there is little variation between the overall MAW and MCW by a few percentage points ranging from 1% to 8% with the exception of "level of scope definition" which has a 15% difference. This is an indication of the internal validity of the results. On the other hand, the standard deviations associated with the impact assessments under the three different project execution conditions are relatively large due to the large dispersion in responses (**see Appendix F**) ranging from 3.65 to 111.77, indicating lack of agreement on how much impact each factor could have on final cost. The standard deviations appear to be larger for outrageous conditions due to the wide dispersion in responses, followed by likely and then perfect conditions. Due to the small sample size, there was no value in carrying out any further statistical analysis. The overall mean assessed weightings (**table 5-4**) indicate that the influence of the final cost determining factors range approximately from "somewhat critical" to "very critical".

5.2.6.2 Overall Cost Overrun Determination – Monte Carlo Simulation

The PLO data values in **table 5-4** were simulated (1,000 iterations) using a Microsoft Excel program to determine the overall potential cost overrun for a unit price contract. The result of this simulation is presented in **figure 5-5** and **table 5-5** below.

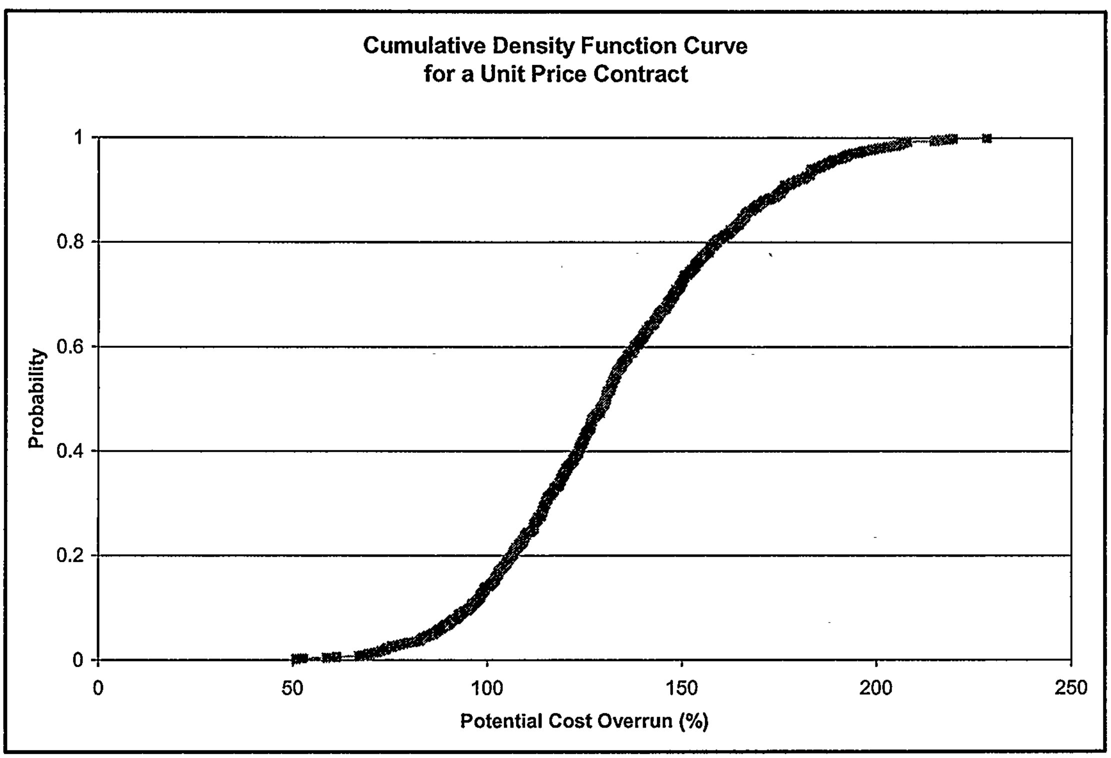

Figure 5-5: Potential Cost Overrun as a percentage of Initial Contract Price

Statistic	Value
Minimum	50.93
Maximum	228.13
Mean	132.91
Standard Deviation	30.79
Coefficient of Variation	23.17%
Percentile	**Value**
5th	86.16
10th	95.87
20th	106.45
30th	114.99
40th	123.50
50th (Median)	130.50
60th	137.89
70th	147.95
80th	158.78
90th	175.67
95th	187.30

Table 5-5: Potential Cost Overrun Statistics for a Unit Price Contract

From **figure 5-5** and **table 5-5**, the mean potential cost impact is 132.91%. The minimum and the maximum values are indications that there is a wide dispersion of the data points in the range of about 51% to 228%. Using the percentile statistics, the 50th percentile (median) for example, shows that the probability of an overrun being less than or equal to the median value of 130.50% is 0.50 and the probability that the overrun is at least the value of the median is also 0.50.

The CDF curve with its positive skew is an indication that data points tend to lean more towards cost overrun than savings.

Figure 5-6 below shows the contribution of each of the seven primary factors to the total cost overrun for a unit price contract with "Change Orders" and "Bid" factors having the highest (22%) and lowest (10%) contributions respectively.

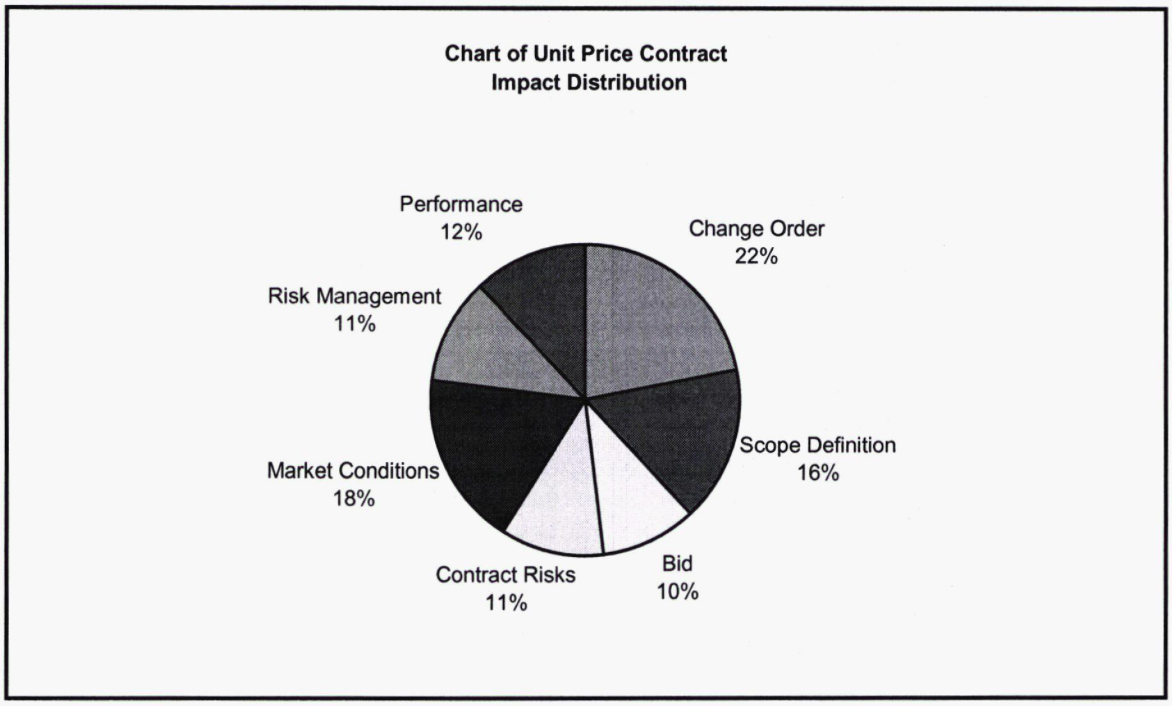

Figure 5-6: Cost Factor Impact as a Function of a Unit Price Contract

The class of estimate which matches a unit price contract according to the cost estimate classification matrix (AACEI 2003) for process industries is the check or control estimate (Class 1 or 2 estimate). This is because unit price contracts are sometimes awarded to the bidder with the lowest lump sum equivalent price although final quantities are usually unknown. This estimate category, with its associated accuracy range, should result in a final cost of –10% to +15% for a Class 1 estimate and from –15% to +20% for a class 2 estimate. The statistical result presented in **table 5-5** indicates an average cost increase in the range of about 51% to just over 228%, which are significantly higher than the estimated accuracy range of a typical Class 1 or 2 estimates.

5.2.7 Cost Plus Contracts

5.2.7.1 Weighting and Impact Analysis

The analysis of weightings and impacts as presented in **Appendix G** are discussed together with the overall results shown in **table 5-6** below.

Primary Cost Factor	Weighting			Overall Impact (%)		
	MAW	MCW	PD	P	L	O
Change Orders	6.42	5.97	7	0.12	12.91	97.85
Level of Scope Definition	6.71	5.63	16	-3.13	10.65	58.59
Bid	5.25	5.15	2	-1.25	5.45	24.74
Contract Risks	5.38	5.44	1	1.65	6.37	30.67
Market Conditions	5.86	6.27	6	3.21	16.85	70.93
Risk Management Issues	5.75	6.41	11	-0.93	5.97	39.48
Performance	6.00	6.40	7	3.33	12.16	41.38

Table 5-6: Overall Weights and Impacts for a Cost Plus Contract

The overall MAW from the table above for the primary cost factors indicate that the influence of these factors on final cost ranges approximately from "somewhat critical" to "very critical". The relatively low standard deviations associated with weightings of both the secondary and primary cost factors ranging from 0.48 to

3.05 (**Appendix G**) show that there was generally an agreement on how critical these factors are in determining final cost. The moderately low variation between the MAW and the MCW (ranging from 1% to 16%) demonstrates some internal consistency in the assignment of weights by respondents. However, the significantly large standard deviations associated with the impact assessments under perfect (3.74-12.90), likely (4.59-26.58) and outrageous (17.24-125.51) conditions indicate lack of agreement on the level of impact each factor could have on final cost. The standard deviations appear to be larger for outrageous conditions, followed by likely and then perfect conditions

5.2.7.2 Overall Cost Overrun Determination – Monte Carlo Simulation

The PLO data values in **table 5-6** were simulated (1,000 iterations) in a Microsoft Excel program to determine the potential cost overrun for a cost plus contract. The result of this simulation is presented in **figure 5-7** and **table 5-7** below.

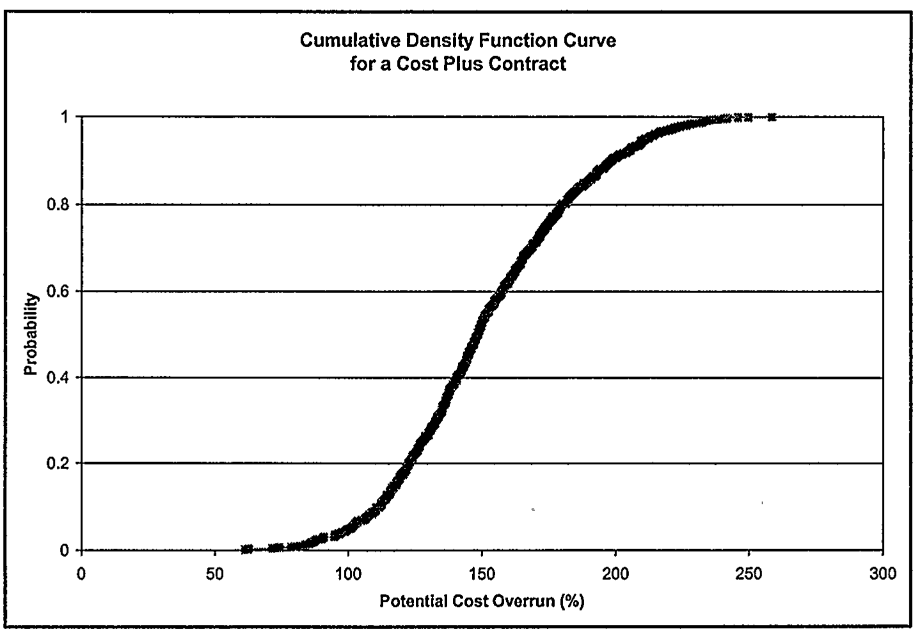

Figure 5-7: Potential Cost Overrun as a percentage of Initial Estimate

Statistic	Value
Minimum	61.44
Maximum	258.53
Mean	151.84
Standard Deviation	33.78
Coefficient of Variation	22.25%
Percentile	**Value**
5^{th}	100.70
10^{th}	111.80
20^{th}	122.71
30^{th}	132.77
40^{th}	140.66
50^{th} (Median)	148.46
60^{th}	157.51
70^{th}	168.72
80^{th}	180.23
90^{th}	198.28
95^{th}	211.10

Table 5-7: Potential Cost Overrun Statistics for a Cost Plus Contract

From **figure 5-7** and **table 5-7**, the average final cost impact is 151.84%%. The minimum (about 61%) and the maximum (about 259%) values are indications that there is a wide dispersion of the data points. The positive skewness of the CDF curve is an indication that data points tend to lean more towards cost overrun than savings. Furthermore **figure 5-8** shows the various contributions per cost factor expressed as a percentage of the total overrun for a cost plus contract with "Change Orders" and "Bid" factors having the highest (24%) and lowest (9%) contributions respectively.

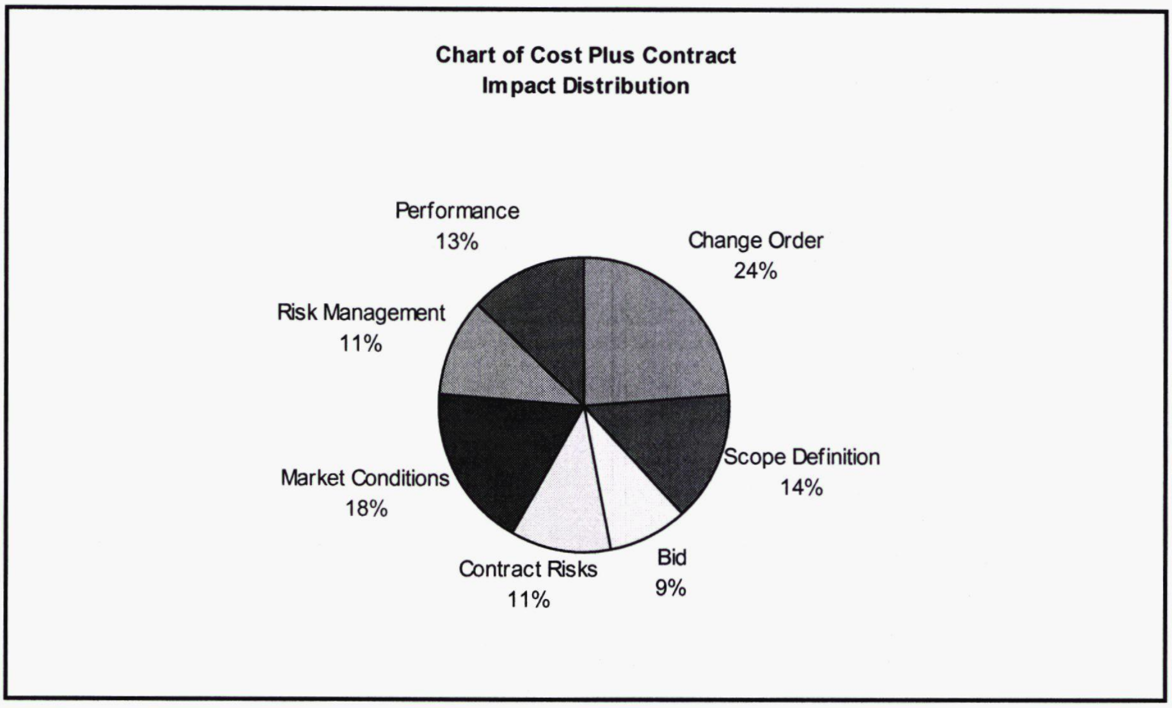

Figure 5-8: Cost Factor Impact as a Function of a Cost Plus Contract

The class of estimate, which matches a cost plus contract according to the cost estimate classification matrix (AACEI 2003) for process industries, is the budget estimate (Class 3 estimate). Cost savings in a Class 3 estimate should range from 10% to 20% on the low side and overruns from 10% to 30%. However, the statistical result presented in **table 5-7** indicates an average cost increase in the range of about 61% to about 259%, which are significantly higher than the estimated accuracy range of a typical budget estimate.

5.2.8 Comparative Analysis of Cost Impacts

From **figures 5-4, 5-6** and **5-8**, "Change Orders" have the highest impact on final cost of construction by 21%, 22% and 24% for stipulated price, unit price and cost plus contracts respectively. Market conditions account for the second highest impact of 16% for a stipulated price contract and 18% each for unit price and cost plus contracts. There are no other clear patterns except that the "Bid" factor produces the lowest impact for each contract type.

The CDF curve in **figure 5-9** below shows that stipulated price and cost plus contracts have very similar cost impact profiles whiles it differs significantly for a unit price contract. From **table 5-3** and **table 5-7**, the impact from the 40th to the 95th percentile is approximately equal. Stipulated price and cost plus contracts have values of 168.13% and 168.72% respectively at the 70th percentile and 198.05% and 198.28% respectively at the 90th percentile. They have values of 98.05% and100.70% at the 5th percentile and 107.80% and 111.80% at the 10th percentile respectively. Although the impacts are generally close at the various percentiles, they are much closer at the upper boundaries as compared to the lower boundary percentiles.

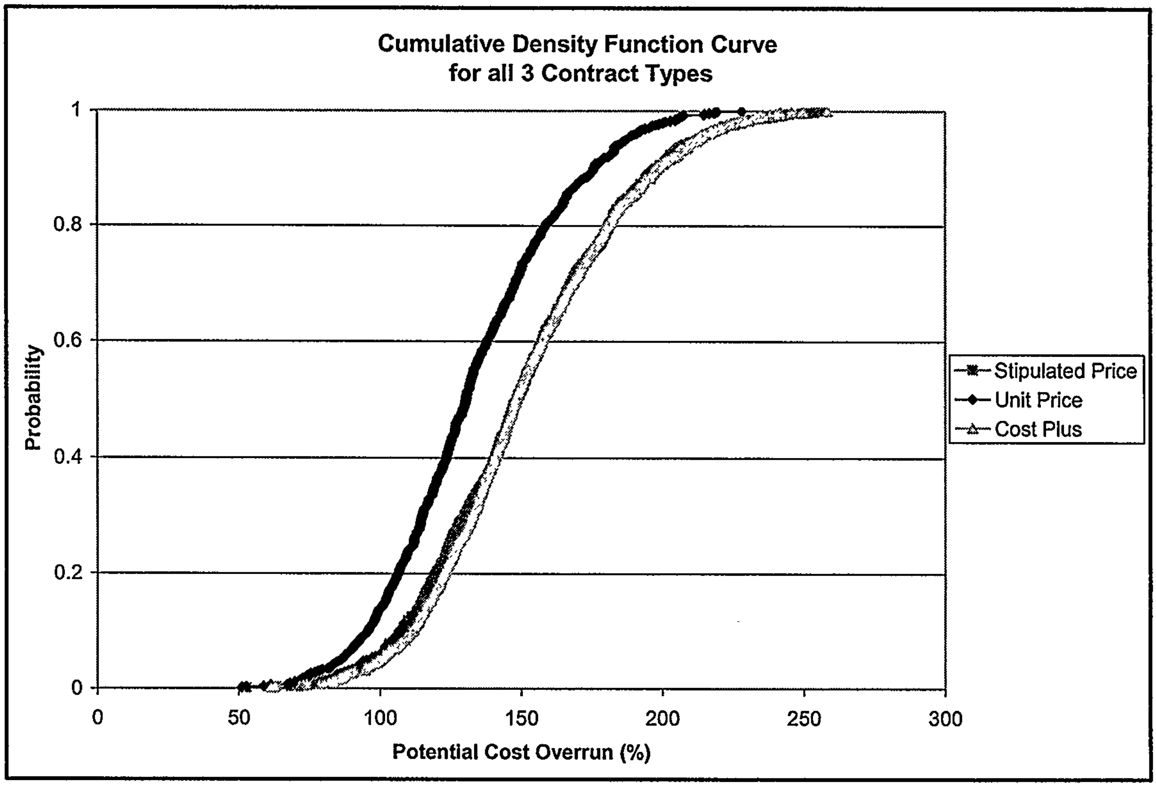

Figure 5-9: Potential Cost Overrun for all 3 Contract Types

5.2.9 Reliability and Validity of Results

With the exception of two participants from the same organization who differed in opinion about the basis of awarding construction contracts during the pilot phase of the study, there was generally an agreement that the award of construction contracts is cost-driven as opposed to "cultural fitness" (view of one of the two differing participants in opinion from the same company). Results from the pilot phase of the study were generally collaborative (repeated nature of opinions) indicating reliability and validity.

With the main phase results, the variability associated with data on the weighting of factors was relatively low as indicated by the measures of dispersion (**Appendix E, F and G**). Furthermore, the Mean Assessed Weighting (MAW) and the Mean Computed Weighting (MCW) for each primary factor should theoretically be approximately equal. The MCW differs from the MAW by just a few percentage points, which is a verification of the internal consistency (reliability) in responses on the weightings. The relatively large variability associated with the cost impacts besides the approximations used in dealing with the cost factor overlaps is an indication that the cost impact data may be fraught with some level of uncertainty and would therefore not be reliable for use in developing models for assessing final cost. If the cost impacts were reliable, it would have been used in developing models for assessing final cost and seeking validation in another phase of the modified Delphi study by using real project data, which would be difficult to obtain though since participants were not willing to give any documentation during the pilot phase of the study. Hence the positive skewness of the CDF curves mainly portray the fact that there is a high tendency to experience significantly large cost overruns in the delivery of Oil and Gas construction projects in Alberta.

CHAPTER SIX CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the qualitative data (obtained from the pilot phase) analysis, it can be concluded that vendors (contractors and subcontractors) are most commonly selected for Oil and Gas engineering construction projects in Alberta, Canada through competitive bidding with price being a major consideration or the only basis for contract award; bidders having undergone pre-screening and/or pre-qualification. It was established that there is usually growth in construction cost and that the difference between bid price (or estimate based on unit rates for some cost plus contracts) and final cost of construction to the owner is accounted for by certain factors that were coded into seven primary categories. These factors were quantified during the main phase of the study and were statistically analyzed. This analysis revealed the extent to which various final cost determining factors influence final cost with respect to the three basic contract types – stipulated price, unit price and cost plus.

This chapter summarizes the findings of this study and presents the conclusions, recommendations, limitations of the study and additions to the existing body of knowledge. Furthermore, it suggests how the results of the study can be applied in Oil and Gas engineering construction contracts. Potential areas for future research are also suggested.

6.1 APPLICATION OF RESULTS

Those who call for bids (typically owners, consultants and contractors) throughout the selection process try to select the most suitable vendor through pre-screening, pre-qualification, and sometimes seeking bid clarifications and conducting pre-award interviews. Nevertheless, construction projects, particularly in the Oil and Gas sector continue to experience significant cost overruns. The assignment of weightings to the various final cost determining factors indicate that the influence level of these factors on the final cost ranges approximately from "somewhat critical" to "very critical" for each contract type. This shows how significant these factors are in determining final cost

Although the results of the simulation cannot be used as models for assessing final cost of vendors at time of bid due to the relatively large variability associated with the cost impacts, it provides valuable information on the overall cost increases to be expected at the end of a project. Final cost increases range from about 53% to 257% for a stipulated price contract, 51% to 228% for a unit price contract and about 61% to 259% for a cost plus contract. Adding a given cost increase (overrun) to the initial price will result in the final cost of a project. "Change Orders" and "Market Conditions" are the greatest contributing factors to the final cost increases with "Bid" factor having the least contribution. "Change Orders" account for 21%, 22% and 24% for stipulated price, unit price and cost plus contracts respectively. "Market Conditions" account for 16% for a stipulated price and 18% each for a unit price and a cost plus contract. The least contributing factor (Bid) accounts for 11%, 10% and 9% of the final cost increases for stipulated price, unit price and cost plus contracts respectively. The simulated results for each contract type generally shows that there is a greater tendency for cost overruns on Oil and Gas engineering construction projects in Alberta as indicated by the positive skewness of the simulated impact data. The highest cost range is associated with stipulated price contracts of approximately 204%, followed by cost plus contracts of about 198% and then unit price contracts of 177%. These cost ranges could serve as a warning and reference guide to bid organizers in being more judicious during bid evaluations.

6.2 CONCLUSIONS AND RECOMMENDATIONS

By use of the competitive bidding process owners, or their authorized agents, attempt to identify and invite the most capable contractors and subcontractors through pre-screening and/or pre-qualification. This notwithstanding, it was discovered that there are certain types of bidders who do submit unrealistically low bids with the hope of recovering money that might have been gambled with in achieving a low bid price at time of bid through the issue of change orders during project execution. Since 9 of 18 respondents stated that contract awards are made to the lowest technically compliant bidder and 2 of 18 that price has a heavier weighting in bid evaluation, it would be misleading for a bid organizer to award a contract to an unrealistically low bidder and expect that the project would be completed at that price. This situation could apply to the "best bid" selection where the contract is awarded to the bidder with the lowest adjusted bid price (5 out of 18 responses). This may not necessarily be the best bid because adjusting bid prices using other performance measures like schedule, quality, safety, etc. of bidders and quantifying them in dollar terms in situations where a bidder has submitted an unrealistically low bid price on purpose or mistakenly could result in the selection of such a bidder. Hence, where price is of great concern to bid organizers, there should be a more judicious approach in evaluating and awarding construction contracts. This is because awarding to the lowest bidder who has intentionally or mistakenly submitted a "cut-price" could result in cost increases way beyond the expectation of the bid organizer or other bidders.

It is, however, evident that not only vendors are liable for such cost increases in initial price. Although 14 out of 18 respondents overall said the difference between initial price and final cost is, or could be, significant especially in low bid situations (though cost increases are also associated with non-low bid situations), the factors that account for the difference in cost show that both owners and bidders are liable for cost increases. For example, design completeness or incompleteness is the owner's liability while omissions by a bidder would be the bidder's liability.

6.3 CONTRIBUTION TO THE BODY OF KNOWLEDGE

The research, based on the interview and survey results, has provided the following contributions to the cost engineering and project management body of knowledge with respect to Oil and Gas engineering construction work in Alberta, Canada:

- Competitive bidding is the most common method by which vendors are selected for Oil and Gas engineering construction work. This process typically involves pre-screening and pre-qualification of vendors, a formal request for the submission of bids and its evaluation. Sometimes, a pre-award interview is conducted with a recommended bidder prior to contract award. To a lesser extent, vendor selection is done through nomination.
- There are two principal bidding philosophies in the construction industry. 1) Submitting a low bid just for purposes of winning the contract and recovering losses through the playing of games during project execution. 2) Submitting a realistic bid regardless of the competition and taking the risk to either win or lose. These philosophies confirm the phantom and fair bidder types described by Crowley and Hancher.
- Construction contracts are typically awarded to the lowest technically compliant bidder (raw or adjusted bid price). This practice appears to be the reason for the submission of "cut-prices" by some vendors. On the other hand, price is considered as one major factor among other pre-determined bid evaluation factors that receive a heavier weighting in selecting a bidder for contract award.

- There is usually a difference between bid price or estimate based on unit rates and final cost of construction to the owner. However, it has been established that the difference in cost is usually higher for the low bid system of contract award.
- Following the result that there is usually growth in cost on construction projects, the factors that account for the difference between initial price (estimate) and final cost were obtained and coded into primary and secondary cost categories. Weightings were assigned to these factors by respondents to indicate their influence in determining final cost. Generally, there was an agreement on how critical these factors were in accounting for the difference between initial estimate and final cost. Overall, the level of influence of these factors on each contract type (stipulated price, unit price and cost plus contracts) ranges approximately from "somewhat critical" to "very critical".
- Besides establishing how critical these factors are in determining final cost of construction at time of bid, the results of the survey provide the impacts (percent) associated with these factors relative to each contract type and project condition. Although there is a wide range of variability associated with the cost impacts besides the approximations used in dealing with the cost factor overlaps, it provides useful information to bid organizers in being wary of the level of cost increases associated with each contract type and their level of confidence. Typical cost increases range from about 53% to 257% for a stipulated price contract, about 51% to 228% for a unit

price contract and about 61% to 259% for a cost plus contract. Within accuracy of this study, the cost overrun range for all the three contract types is about 50% to 260%

- This thesis in general has provided increased understanding of what is happening in the Oil and Gas engineering construction market place. This knowledge can be used as a basis in moderating the games that are played in the construction industry by thoroughly scrutinizing bids submitted by vendors. Furthermore, these findings may help in future research in developing a model for assessing the final cost of construction at time of bid, which is discussed in section 6.5 "Suggested Areas for Future Research".
- Given that Oil and Gas construction accounts for about 46% of the total Canadian engineering construction (comprising Marine, Transportation, Waterworks, Sewage, Electric Power, Communication, Oil & Gas, Mining and "Others") , any improvements in the efficiency of the vendor selection process has the potential of large cost savings besides improving the Canadian economy.

6.4 LIMITATIONS OF FINDINGS

The major work in this study was completed in the main phase, which had 14 responses out of the 18 questionnaires mailed. Although the response rate of 78% is acceptable, the non-responses could introduce some bias in results. In this regard, the results of this study only reflect the views and opinions of those who responded. This may imply that the views presented may not necessarily represent the entire cross section of this industry (Oil & Gas). The respondents are generally industry professionals with an average of 24 years of work experience in the construction industry with a range of 12 to 35 years experience. The sample was limited to the Oil and Gas industry in Alberta, Canada using the snowball sampling technique. Thus, the results of this study can only be applied to the Oil and Gas industry, but cannot necessarily be applied to other industries.

Another major limitation to this study is that assignment of weights and impacts were not done uniformly based on project characteristics such as size of project, complexity, nature (new, maintenance, upgrading etc.), and type of procurement system (example, low bid). There was also the view that there is usually not much difference between initial price and final cost from a sub-contract perspective. These are further discussed in detail under “suggested areas for future research”.

6.5 SUGGESTED AREAS OF FUTURE RESEARCH

The variability associated with the cost impact assessments as indicated by the various measures of dispersion is quite significant. No consideration is given to issues of project size, complexity, type of procurement system and more. In this regard, the following are suggestions for future research:

- The indication that there is usually not much difference between initial price or estimate and final cost for subcontracts should be further investigated.
- For each subcontract or main contract, projects should be classified according to size (dollars), complexity and, say, nature of project (new construction, maintenance, upgrading etc.). This would enable the results of the study to be used more meaningfully in the development of models for assessing final cost of construction at time of bid. Furthermore, there are different competition-based bid award systems – low bid, average bid and value-based award systems. It is recommended that future research should be carried out by identifying which procurement system is in use. This would ensure which procurement system the results would specifically apply to.
- Most of the secondary cost code factors had some overlaps, which was not realized until after data collection. Averaging the impacts associated with these factors was done as an approximation although the extent of the overlaps is not known. It is hereby recommended that instead of assessing the impacts associated with the secondary cost factors, which

were used in determining the impacts for the primary cost factors, the secondary factors should be categorized and used to provide a definition for the primary factor. In this case, the assessment of impacts would only be done for the primary cost factors, which is a simpler approach than was done in this research. Hence, there would be no overlaps. Some metrics (performance measures) should also be developed in assessing the final cost of construction if a particular bidder is selected for contract award.

- The use of case studies would have been the best approach in conducting this study. However, participants during the pilot interview were not willing to provide any documentary evidence. It was therefore impossible to do a case study during the main phase of the study. Where possible, it would be of great advantage in collecting data based on past executed projects from company reports or monitoring a project from the time of commencement to completion. This may seem difficult since companies consider what they do as trade secrets or proprietary in nature.

The potential benefits arising from better contract award procedures cannot be overemphasized. The significant cost overruns in Oil and Gas engineering construction in Alberta, Canada has been traced to 7 primary factors – Change Orders, Level of Scope Definition, Bid Process/Duration, Contract Risks, Market Conditions, Risk Management and Performance issues. Conducting further studies and developing a model that can be used to assess final cost of construction at time of bid using these factors would help realize better profits, which are usually eroded due to significant cost overruns.

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- **APPENDIX A**

A1:Capital Expenditures on Canadian Construction

CLASSIFICATION	1994	1995	1996	1997
	$ millions			
Total capital expenditures on construction	**81,444.20**	**76,391.30**	**80,548.80**	**89,679.00**
Building construction	51,057.10	45,770.40	50,995.70	55,814.10
Residential building construction	34,921.50	29,185.80	32,575.20	37,406.50
Single detached houses	11,591.60	8,836.90	10,874.90	12,161.40
Semi-detached houses	1,061.80	729.5	802.4	1,054.00
Apartments and row houses	4,362.10	3,574.40	3,141.90	3,696.00
Other residential buildings	17,906.00	16,045.10	17,755.90	20,495.00
Non-residential building construction	16,135.60	16,584.60	18,420.50	18,407.70
Industrial building construction	3,006.10	3,243.00	4,236.30	4,057.20
Plants - manufacturing, processing and assembling goods	1,865.60	1,939.10	2,934.60	2,875.40
Other industrial buildings	1,140.40	1,303.90	1,301.60	1,181.90
Commercial building construction	6,250.80	6,264.50	6,935.90	7,209.80
Office buildings	2,598.10	2,507.40	2,750.80	3,053.10
Shopping centres, malls, stores	1,622.60	1,329.30	1,680.10	2,036.70
Indoor recreational buildings	620.2	1,024.40	1,041.80	744.1
Other commercial buildings	1,409.90	1,403.20	1,463.20	1,375.80
Institutional building construction	4,931.30	4,982.10	4,955.00	4,792.00
Schools, colleges, universities	2,261.20	2,328.70	2,634.80	2,606.50
Hospitals, health centres, clinics	1,283.60	1,265.20	1,182.50	1,061.80
Nursing homes, homes for the aged	276.4	445.5	394.1	334.9
Penitentiaries, detention centres	262.6	289.3	188.9	361.8
Other institutional and governmental construction	768.4	601.7	492.3	326.4
Other non-residential construction	1,947.40	2,095.00	2,293.30	2,348.60
Engineering construction	30,387.10	30,620.90	29,553.10	33,864.90
Marine engineering construction	492.1	445	448.6	453.7
Transportation engineering construction	6,032.20	6,435.80	6,157.50	5,758.40
Waterworks engineering construction	904.3	1,140.00	1,360.20	1,671.70
Sewage engineering construction	1,501.30	1,584.50	1,389.90	1,449.10
Electric power engineering construction	3,965.00	3,440.80	2,934.70	2,411.90
Communication engineering construction	1,446.30	1,298.30	1,879.80	2,064.00
Oil and gas engineering construction	13,720.50	13,474.00	12,891.30	17,187.40
Mining engineering construction	1,117.10	1,407.40	1,476.60	1,869.50
Other engineering construction	1,208.40	1,395.20	1,014.50	999.3
Source: Statistics Canada, CANSIM II, table 029-0002 and Catalogue no 61-223-XIB.				
Last modified: October 13, 2003				

Table A-1

Appendix A2: Summary of Capital Expenditures on Canadian Construction

CLASSIFICATION	AVERAGE (1994 - 1997)	
	$Billions	**Percentage**
Building Construction	50.9	62%
Engineering Construction	31.1	38%
Total Exp. on Construction	**82.0**	**100%**
ENGINEERING CONSTRUCTION		
Marine	0.5	1%
Transportation	6.1	20%
Waterworks	1.3	4%
Sewage	1.5	5%
Electric Power	3.2	10%
Communication	1.7	5%
Oil & Gas	14.3	46%
Mining	1.5	5%
Others	1.2	4%
Total Exp. On Eng. Construction	**31.30**	**100%**

Table A-2

Appendix A3: Top Ten Valued Construction Projects In Canada

Project	Location	Start	End	$Value (M)
Oil Sands Plant Expansion	Fort McMurray	1997	2008	$8,244
Greenfields Oil Sands Project	Muskeg River (Strathcona)	1999	2003	$6,807
Road and Rail Expansions	Montreal, PQ	2000	2010	$6,615
Project Horizon	North of Fort McMurray	2004	2011	$5,263
Pearson Airport Dev't. Project	Toronto	1998	2008	$4,677
Springdale Community	Brampton	1991	2006	$4,526
Churchill River Power	Churchill Falls	2005	2012	$4,257
Oil Sands Mining / Extraction Plant	Fort Hills	2002	2008	$3,631
Oil Sands Mine	Near Fort McMurray	2002	2010	$3,399
Voyageur	Near Fort McMurray	2002	2010	$3,213

Table A-3

APPENDIX B

PILOT PHASE INTERVIEW GUIDE

General Information

Questions will be mostly open-ended for the pilot and the first phase of the main study. The rest of the phases are likely to comprise closed questions or combinations of open and closed questions. Subsequent questions will solicit information about professional experience and opinion. These questions will be designed to add specific detail to information gained in earlier rounds. These will be designed to seek participants' experience and opinions on the contractor selection process through competitive bidding and other approaches, and factors that can help in assessing the likely final cost in construction at bid time.

1. DEMOGRAPHIC INFORMATION (TO BE KEPT CONFIDENTIAL)

1.1 Name: ____

Organization: ____

Telephone: __________ Fax: ____________ E-mail: ______________

1.2 Please specify your current position in your organization: ________________________

1.3 How many years of work experience do you have in the Construction Industry? ________

1.4 Please specify your current role in industry:
Owner Consultant Prime Contractor Sub-Contractor
Other (please specify): ____________________________

1.5 What percentage (estimate) of your company's annual construction volume involves industrial projects in the oil and gas industry? _______________

1.6 What is your annual construction volume in Canadian Dollars? $________

<u>Questions</u>:

1. Describe your current practice for the selection of construction contractors and subcontractors through competitive bidding or other approaches.

2. What is/are the basis on which construction contracts are awarded?

3. A contractor with a successful tender is selected under various criteria but the low bid system is the most commonly accepted (Hung 2002, page 36). What is your opinion about this statement? Do you think there is a significant difference between the low bid and the final construction cost? If yes, what factors does it depend on?

4. Are you currently able to assess the difference between bid price and the likely final cost of construction at the bid evaluation stage prior to contract award? If yes, how?

5. If you answered no, then please respond to this question. If there could be a mechanism by which the final cost of construction of each bidder could be assessed during bid evaluation, how useful will that be to the construction industry?

6. (i) Would you please be willing to participate in another round of the interview?
(ii) Would you please recommend two or three potential participants in other organizations to interview with respect to this research?

REFERENCE

1. Hung, T. T. "Prequalification and Qualified Tendering Group: A Perspective from the Hong Kong Ground Investigation Industry" Cost Engineering Journal, Vol.44, No. 5, May 2002.

APPENDIX C

Assessing Final Cost of Construction at Bid Time

Ganyo Nutakor, B.Sc.

This consent form, a copy of which has been given to you is only part of the process of informed consent required by the University of Calgary Ethics Committee. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about anything mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

Invitation to Participate: I am researching "Assessing Final Cost of Construction at Bid Time" and you are invited to participate. My name is Ganyo Nutakor and I am a Master of Science (M.Sc.) Student at the University of Calgary, Department of Civil Engineering. This research study is being funded by NSERC, SSHRC, Canadian Project Forum and industry sponsors through the chair in the Project Management held by Dr. Hartman with the Specialization Program at the University of Calgary and is in partial fulfillment of the M.Sc. degree requirements.

Purpose of Research: The purpose of this research is to develop a mechanism to assess or predict the difference between bid price and the probable final cost in construction as an aid to owners and consultants in selecting the most suitable contractor through a modified competitive bidding process in the construction industry in Alberta. You were selected as a possible participant in this study because of your professional knowledge and/or experience in construction contracting. If you decide to participate, you will be one of between 30 and 60 industry experts participating in this study.

Research Method: If you decide to participate, we will either interview you directly or collect information through a questionnaire. The face-to-face interview will take about one hour. The interview will (with your permission) be tape recorded onto audiocassette, and then transcribed onto paper. The interviews will yield data about factors that account for the difference between bid price and the final cost in construction.

Your Professional Opinion: You will be asked for your professional knowledge about the construction contractor selection process and the factors that account for the difference between bid price and the final construction cost. The overall (summary) research results will be shared with the research participants. The research results may be beneficial to research participants in many ways such as reviewing current practices in contractor selection and the variables that determine the likely final construction cost that should be considered during the bid evaluation process in order to improve the selection process.

Confidentiality, Anonymity & Security of Data: If you decide to participate, your identity as a participant in this study, and any other personal information gathered about you during the study will be kept strictly confidential and will never be made public. All data containing personal information from which you could be identified will be stored in a locked file cabinet in my office during the study. It will only be available to me and to my supervisor. Electronic data will be password protected. All published results of the study will contain only statistical or group data from which no individual participant can be identified. Raw data will be retained for up to five years after completing the study and stored in a secured location by my supervisor. Then my supervisor will have them destroyed.

The Right to Say No: You are being asked to make a voluntary decision as to whether you wish to participate in this study. Please read and think about the information given above. If there is any part of the information you do not understand, please ask me to explain it. If you would like to consult with someone not associated with this study that will be acceptable, too. If you decide not to participate, or if you later decide to discontinue your participation, your decision will not affect your present or future relations with the University of Calgary. Upon request, a copy of the information, data, and results will be made available to you. **You will always be free to discontinue participation at any time**, and all data collected up to that time as a result of your partial participation will be destroyed without being used in the study. If you decide to participate, please provide your signature as indicated below.

What Your Signature Means: Your signature below on this Consent Form indicates that you have read, considered and understood to your satisfaction the information regarding participation in this research project and agree to take part as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have any further questions concerning matters related to this research, please contact:

Contact Information

Ganyo Nutakor
Project Management Specialization
Dept. of Civil Engineering, University of Calgary
Telephone: (403) 262-4452 / 220-6185
Email: gnutakor@ucalgary.ca

Dr. Francis Hartman (Research Supervisor)
Project Management Specialization
Dept. of Civil Engineering, University of Calgary
Telephone: (403) 220-7178
Email: fhartman@ucalgary.ca

If you have any questions concerning your participation in this project you may also contact the Research Service Office at 220-3782 and ask for Mrs. Patricia Evans.

Signature of Participant ____________________________ Date ______________

Print Name: ____________________________________

Signature of Investigator __________________________ Date ______________

A copy of this consent form has been given to you ***for your records and reference***

APPENDIX D

ASSESSING FINAL COST OF CONSTRUCTION AT BID TIME (IN THE OIL, GAS AND PETROCHEMICAL INDUSTRY)

SUMMARY OF PILOT INTERVIEW RESULT

The following is a summary of the key observations from the first phase of this study. Construction contractor or subcontractor selection is done, typically, through competitive bidding. There are limited cases of using negotiation, alliance or partnership agreements or a nominated sole source based on the owner's prerogative. The competitive bidding process by consensus begins with a long list of contractors/subcontractors who are invited to pre-qualify for inclusion in a bid list. Typical factors considered in this process are safety record, current workload, availability of personnel, record of previous projects executed, geographic location of work relative to contractor, financial capability, union affiliations etc. Those who meet the pre-qualification criteria are then invited to submit bids through competitive bidding (typically sealed bids).

There were basically two opinions on who is awarded the contract.

1. The contractor or subcontractor with the lowest price (low bid)
2. The contractor or subcontractor with the best bid (best people, best schedule, best price, best quality, best safety program, best cultural fitness and trust)

On the question of assessing the difference between bid price and final cost of construction to the owner, several factors were identified as accounting for this difference. These factors have been used in formulating the second round questionnaire. The purpose of this questionnaire is to provide an overview of the study results in round one and to present the second round of questions based on responses from the initial phase.

QUESTIONNAIRE – ROUND TWO-DELPHI STUDY

This survey, which is the second phase of the Delphi study, is to seek consensus on responses from the round one interview. It is also intended to identify the critical factors that account for the difference between bid price (for stipulated price contracts) or estimate based on unit rates (for cost plus and unit price contracts) and the final cost of construction.

You are reminded that all responses in the study are strictly confidential and will remain protected at all times. Responses to the survey will result in statistical or group data, which will be made available to you in the future. Such data will, at all times, be aggregated such that individual participants and their responses cannot be isolated or identified. We estimate that this questionnaire will take about **40 minutes** of your time.

Question: Please review the list in the table below and add other factors as deemed necessary, which could account for the difference between BID PRICE (OR ESTIMATE BASED ON UNIT RATES) and the FINAL COST OF CONSTRUCTION in the Oil, Gas and Petrochemical Industry. On a scale of 1 to 7, please assign a weight to each factor where:

1 = not at all critical, **2** = not critical
3 = somewhat not critical **4** = neutral
5 = somewhat critical **6** = critical **7** = very critical

Also, estimate the percentage (%) IMPACT of each factor on the final cost of construction under Perfect (**P**), Likely (**L**) and Outrageous (**O**) conditions with respect to each contract type (Stipulated Price, Cost Plus and Unit Price).

<u>**Premise for Response on IMPACT Assessment and Definitions**</u>

The IMPACT (%) in the table below should show your assessment of the range of change between Bid (or estimate based on unit rates) and Final Cost as a result of the FACTOR you are considering. For each of the FACTORS listed in the table, consider three different situations you have experienced that FACTOR, which meets each of the Perfect (P), Likely (L) and Outrageous (O) conditions. Perfect (P), Likely (L) and Outrageous (O) are defined for the purpose of this study as follows:

Perfect (**P**):	Is the cost of time and effort or money required to achieve an objective under optimal conditions or when all conditions are favourable.
Likely (**L**):	Most likely conditions (neither perfect nor outrageous) or what happens/is expected on everyday construction project delivery.
Outrageous (**O**):	What it takes if there is a badly mess up and everything else goes wrong, too.

EXAMPLE:

If your experience is that under perfect conditions, "Number and Magnitude of Changes" (Under Item 1 in Table) can reduce final cost relative to bid price by up to 2% and the likely change is an increase of 5% and in a worst case scenario could be as much as 200%, for a stipulated price contract, then the PLO for this type of contract will be –2, +5 and +200.

NOTE:

Cells with a dash (-) sign should be left blank

Questionnaire: Round Two Delphi Study

Item	Factor	Contract Type											
		Stipulated Price				Cost Plus				Unit Price			
		Weight	% Impact			Weight	%Impact			Weight	%Impact		
		(1 to 7)	P	L	O	(1 to 7)	P	L	O	(1 to 7)	P	L	O
1	**Change Orders (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Number & magnitude of changes												
	Change order administration/mgt.												
	Changes in work condition/situation												
	Variations in quantity												
2	**Level of Scope Definition (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Design or engineering completeness												
	Differences in opinion as to scope												
	Change in scope of work												
	How well responsibilities are defined												
	Thoroughness of risk analysis on design												
	Inconsistent documentation												
	Right contractual terms												
3	**Bid (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Time to bid												
	Clarity of request for bids												
	Mistakes in contractor's or sub's bid												
	Omissions by bidder												
	Completeness of bid package												
	Thoroughness of pre-award interview												
	Bid Clarification												
4	**Contract Risks (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Higher contract administration costs												
	Litigious nature of owner (buyer)												
	Litigious nature of contractor (seller)												
	Litigious nature of designer												
5	**Market Conditions (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Change in wage rates												
	Change in material prices												
	Quality and availability of workforce												

Item	Factor	Contract Type											
		Stipulated Price				Cost Plus				Unit Price			
		Weight (1 to 7)	%Impact			Weight (1 to 7)	%Impact			Weight (1 to 7)	%Impact		
			P	L	O		P	L	O		P	L	O
6	**Risk Management Issues (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Job location												
	Contractor's construction management expertise												
	Owner's Const. Mgt. expertise												
	Risk allocation to the right party												
	Whether bidder has assessed the difficulty of the work correctly or not												
7	**Performance (Overall Weight)**		-	-	-		-	-	-		-	-	-
	Rework (due to lower quality by contractor or subcontractor												
	Rework due to late changes by owner or designer												
	Failing to meet specifications due to interpretation differences												
	Owner's influence on vendor and thus affecting schedule												
	Effect of site productivity												
	Field supervision costs												

PARTICIPATING IN NEXT ROUND OF STUDY

Please underline the appropriate option below.
Are you interested in receiving a feedback and participating in the next round of this study?

YES NO

COMPLETED SURVEY OR QUERIES

Please E-mail/fax this completed survey or queries to:

GANYO NUTAKOR

Project Management Specialization, Department of Civil Engineering,

2500 University Drive NW, Calgary, AB. T2N 1N4

E-mail: gnutakor@ucalgary.ca

Fax: (403) 282-7026 Tel: (403) 220-6185 / 262-4452

Thanks For Your Valuable Time And Contribution!

APPENDIX E

DATA ANALYSIS – STIPULATED PRICE CONTRACTS

Item	Factor	WEIGHTING STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	8	(3, 7)	6.25	1.3887	22.22
	Number and magnitude of changes	14	(4, 7)	6.36	0.9287	14.61
	Change order administration/management	14	(2, 7)	5.14	1.5119	29.40
	Change in work condition/situation	14	(4, 7)	5.64	1.0818	19.17
	Variations in quantity	14	(4, 7)	6.00	1.2403	20.67
2	**Level of Scope Definition (Overall Weight)**	8	(2, 7)	6.25	1.7525	28.04
	Design or engineering completion	14	(4, 7)	6.36	1.0082	15.86
	Differences in opinion as to scope	14	(2, 7)	4.71	1.9386	41.12
	Change (increase or decrease) in scope of work	14	(3, 7)	6.07	1.2688	20.90
	How well responsibilities are defined	14	(3, 7)	4.86	1.4600	30.06
	Thoroughness of risk analysis on design	14	(2, 7)	4.86	2.0327	41.85
	Inconsistent documentation (quality of bid package)	14	(2, 7)	5.86	1.4600	24.93
	Right contractual terms	14	(3, 7))	5.29	1.5898	30.08
3	**Bid (Overall Weight)**	8	(4, 7)	5.75	0.8864	15.42
	Time to bid	14	(2, 7)	5.00	1.6172	32.34
	Clarity of request for bids	14	(2, 7)	5.50	1.5064	27.39
	Mistakes in contractor's or subcontractor's bid	14	(4, 7)	5.43	1.0894	20.07
	Omissions by bidder	14	(2, 7)	5.21	1.6257	31.18
	Completeness of bid package	14	(4, 7)	6.07	0.9973	16.43
	Thoroughness of pre-award interview	14	(1, 7)	5.00	1.7974	35.95
	Bid clarification	14	(2, 7)	4.93	1.5913	32.29
4	**Contract Risks (Overall Weight)**	8	(4, 7)	5.63	0.9161	16.29
	Higher contract administration costs	13	(2, 6)	4.69	1.4367	30.62
	Litigious nature of owner (buyer)	13	(4, 7)	5.38	1.1209	20.82
	Litigious nature of contractor or Subcontractor	13	(3, 7)	5.69	1.3156	23.11
	Litigious nature of Designer (Consultant)	13	(2, 7)	5.23	1.3634	26.07
5	**Market Conditions (Overall Weight)**	8	(3, 7)	5.75	1.2817	22.29
	Change in wage rates	14	(2, 7)	4.79	1.4769	30.86
	Change in material prices	14	(2, 7)	4.79	1.5281	31.93
	Quality and availability of work force	14	(4, 7)	5.86	1.0995	18.77

Item	Factor	WEIGHTING STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	8	(3 7)	5.25	1.2817	24.41
	Job location	14	(2, 7)	5.07	1.5424	30.41
	Contractor's construction management expertise	14	(4, 7)	5.93	0.9973	16.82
	Owner's construction management expertise	14	(4, 7)	5.50	1.1602	21.10
	Risk allocation to the right party	13	(2, 7)	5.38	1.3868	25.75
	Whether bidder has assessed the difficulty of the work correctly or not	13	(2, 7)	6.00	1.5275	25.46
7	**Others/Performance (Overall Weight)**	8	(1, 7)	5.50	2.0000	36.36
	Rework (Due to lower quality by contactor or subcontractor)	14	(2, 7)	5.00	1.8810	37.62
	Rework due to late changes by owner or designer	14	(2, 7)	6.07	1.3848	22.81
	Failing to meet specifications due to interpretation differences	14	(3, 7)	5.29	1.2667	23.96
	Owner's influence on contractor or subcontractor and thus affecting schedule	13	(2, 7)	5.38	1.5566	28.91
	Effect of site productivity	14	(1, 7)	5.57	1.8694	33.55
	Field supervision costs	13	(4, 7)	5.31	1.1094	20.90

IMPACT UNDER PERFECT CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(-20, 10)	-1.21429	8.6218	710.03
	Change order administration/management	14	(-30, 2)	-4.35714	9.2288	211.81
	Change in work condition/situation	14	(-20, 15)	-0.57143	8.2622	1445.88
	Variations in quantity	14	(-10, 5)	-1.15385	4.1802	362.29
	Average			**-1.82418**		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	14	(-10, 5)	-0.64286	5.8125	904.17
	Differences in opinion as to scope	14	(-10, 5)	-1.07143	5.7038	532.35
	Change (increase or decrease) in scope of work	14	(-5, 10)	1.642857	4.3075	262.20
	How well responsibilities are defined	14	(-2, 5)	0.428571	1.5549	362.80
	Thoroughness of risk analysis on design	14	(-15, 7)	0.00000	4.8358	-
	Inconsistent documentation (quality of bid package)	14	(-15, 15)	1.00000	6.1644	616.44
	Right contractual terms	14	(-20, 5)	-1.14286	7.2839	637.34
	Average			**0.030612**		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	14	(-15, 10)	0.428571	6.2353	1454.91
	Clarity of request for bids	14	(-15, 10)	-0.50000	6.9365	1387.31
	Mistakes in contractor's or subcontractor's bid	14	(-5, 10)	0.857143	4.7533	554.55
	Omissions by bidder	14	(-25, 2)	-3.07143	8.5707	279.04
	Completeness of bid package	14	(-15, 5)	-2.21429	5.7669	260.44
	Thoroughness of pre-award interview	14	(-15, 5)	-0.57143	4.6029	805.51
	Bid clarification	13	(-15, 5)	02.07692	5.1875	249.77
	Average			**-1.02119**		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(-20, 5)	-2.91667	6.9604	238.64
	Litigious nature of owner (buyer)	12	(-10, 10)	0.166667	6.0578	3634.68
	Litigious nature of contractor or Subcontractor	12	(-5, 10)	0.333333	4.9969	1499.09
	Litigious nature of Designer (Consultant)	12	(-5, 10)	1.000000	3.5929	359.29
	Average			**-0.35417**		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(-2, 5)	0.923077	2.0599	223.17
	Change in material prices	13	(-5, 5)	-0.15385	2.9678	1929.05
	Quality and availability of work force	13	(-10, 10)	0.461538	4.6119	999.24
	Average			**0.53850**		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(-10, 10)	0.00000	5.7525	-
	Contractor's construction management expertise	13	(-10, 10)	-2.84615	6.4141	225.36
	Owner's construction management expertise	13	(-15, 10)	-2.30769	6.5877	285.47
	Risk allocation to the right party	12	(-10, 10)	-1.00000	5.1698	516.98
	Whether bidder has assessed the difficulty of the work correctly or not	12	(-10, 10)	-1.75000	5.3449	305.42
	Average			$\boxed{1.58077}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(-15 2)	-1.00000	4.3779	437.80
	Rework due to late changes by owner or designer	13	(-10, 5)	0.15384	3.9968	2597.92
	Failing to meet specifications due to interpretation differences	13	(-5, 2)	-0.61538	2.0631	335.25
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(-5, 15)	2.33333	4.9421	211.80
	Effect of site productivity	13	(-15, 20)	2.23077	9.9428	445.71
	Field supervision costs	12	(-10, 5)	-0.25000	3.4411	1376.42
	Average			$\boxed{0.475427}$		

IMPACT UNDER LIKELY CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(0, 25)	12.21429	6.9524	56.92
	Change order administration/management	14	(0, 20)	6.571429	5.9318	90.27
	Change in work condition/situation	14	(0, 25)	9.642857	7.8015	80.90
	Variations in quantity	13	(0, 30)	11.76923	9.8247	83.48
	Average			10.04945		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	13	(-5, 30)	14.00000	9.9833	71.31
	Differences in opinion as to scope	13	(0, 20)	7.923077	5.3457	67.47
	Change (increase or decrease) in scope of work	12	(5, 50)	20.16667	15.5612	77.16
	How well responsibilities are defined	12	(0, 20)	7.583333	8.2733	109.10
	Thoroughness of risk analysis on design	13	(-5, 40)	8.230769	11.8684	144.20
	Inconsistent documentation (quality of bid package)	13	(-5, 50)	15.15385	17.4444	115.12
	Right contractual terms	13	(0, 20)	9.230769	8.9084	96.51
	Average			11.75549		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(-2, 25)	8.00000	8.5926	107.41
	Clarity of request for bids	13	(-5, 25)	5.615385	8.4018	149.62
	Mistakes in contractor's or subcontractor's bid	13	(-5, 20)	9.153846	14.1235	154.29
	Omissions by bidder	13	(-1, 50)	6.153846	13.3906	217.60
	Completeness of bid package	13	(0, 50)	8.538462	13.5254	158.41
	Thoroughness of pre-award interview	13	(-5, 20)	4.384615	6.5643	149.71
	Bid clarification	13	(-5, 30)	6.846154	11.0819	161.87
	Average			6.956044		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(0, 20)	3.750000	5.9867	159.85
	Litigious nature of owner (buyer)	12	(-5, 20)	6.416667	7.1916	112.08
	Litigious nature of contractor or Subcontractor	12	(0, 25)	6.500000	7.8451	120.69
	Litigious nature of Designer (Consultant)	12	(0, 25)	6.083333	6.7885	111.59
	Average			5.68750		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(0, 10)	4.769231	3.6091	75.67
	Change in material prices	13	(0, 15)	4.538462	4.2743	94.18
	Quality and availability of work force	13	(0, 10)	6.076923	4.7690	78.48
	Average			9.96150		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	11	(0, 25)	8.363636	7.3112	87.42
	Contractor's construction management expertise	12	(-5, 20)	3.750000	7.0301	187.57
	Owner's construction management expertise	12	(-3, 15)	3.083333	4.9627	160.95
	Risk allocation to the right party	11	(-10, 20)	6.000000	9.8590	164.32
	Whether bidder has assessed the difficulty of the work correctly or not	11	(-10, 40)	10.90909	18.4144	168.80
	Average			$\boxed{6.421212}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(0, 20)	5.307692	6.9087	130.16
	Rework due to late changes by owner or designer	13	(0, 20)	8.769231	6.1935	70.63
	Failing to meet specifications due to interpretation differences	13	(0, 25)	6.153846	8.5814	139.45
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(0, 20)	7.000000	8.0340	114.77
	Effect of site productivity	13	(0, 50)	13.38462	17.7649	132.73
	Field supervision costs	12	(0, 10)	3.500000	3.5032	100.09
	Average			$\boxed{7.352564}$		

IMPACT UNDER OUTRAGEOUS CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(25, 500)	138.8571	133.1534	95.89
	Change order administration/management	14	(2, 100)	54.3571	37.9161	69.75
	Change in work condition/situation	14	(5, 300)	81.0000	84.7721	104.66
	Variations in quantity	13	(3, 200)	67.9231	55.5149	81.73
	Average			85.5343		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	14	(5, 300)	92.5000	86.5970	93.62
	Differences in opinion as to scope	13	(0, 50)	26.6923	19.0105	71.22
	Change (increase or decrease) in scope of work	12	(20, 300)	97.5000	89.2519	91.54
	How well responsibilities are defined	12	(2, 100)	42.2500	39.1480	92.66
	Thoroughness of risk analysis on design	13	(2, 100)	33.5385	34.2019	101.98
	Inconsistent documentation (quality of bid package)	13	(2, 100)	45.5385	37.5780	82.52
	Right contractual terms	13	(3, 100)	31.1538	33.4361	107.33
	Average			52.7390		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	14	(2, 200)	44.8571	55.1360	122.91
	Clarity of request for bids	14	(5, 100)	33.4286	37.7903	113.05
	Mistakes in contractor's or subcontractor's bid	14	(4, 100)	28.2143	33.0295	117.07
	Omissions by bidder	14	(2, 200)	33.4286	54.5100	163.06
	Completeness of bid package	14	(3, 200)	40.5000	56.8409	140.35
	Thoroughness of pre-award interview	14	(0, 100)	20.4286	27.3544	133.90
	Bid clarification	13	(2, 100)	32.3077	37.1582	115.01
	Average			33.3093		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(1, 100)	18.0000	27.1996	151.11
	Litigious nature of owner (buyer)	13	(0, 500)	80.3077	139.0769	173.18
	Litigious nature of contractor or Subcontractor	13	(5, 500)	96.6923	132.5257	137.06
	Litigious nature of Designer (Consultant)	13	(0, 500)	75.7692	138.6724	183.02
	Average			67.6923		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(2, 200)	28.4615	53.5547	188.17
	Change in material prices	13	(1, 200)	28.3846	53.1720	187.33
	Quality and availability of work force	13	(2, 200)	46.3077	69.2380	149.52
	Average			65.7692		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	11	(1, 100)	40.1818	34.9366	86.95
	Contractor's construction management expertise	11	(10, 100)	39.0909	39.6748	101.49
	Owner's construction management expertise	12	(5, 100)	35.4167	34.9167	98.59
	Risk allocation to the right party	12	(5, 200)	47.9167	59.0923	123.32
	Whether bidder has assessed the difficulty of the work correctly or not	11	(5, 100)	40.6364	36.3793	89.52
	Average			$\boxed{40.6485}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(2, 100)	30.5385	40.3560	132.15
	Rework due to late changes by owner or designer	13	(2, 100)	40.5385	35.1962	86.82
	Failing to meet specifications due to interpretation differences	13	(3, 500)	20.6154	17.8164	86.42
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(5, 100)	30.7500	33.1447	107.79
	Effect of site productivity	13	(5, 150)	47.6923	52.0663	109.17
	Field supervision costs	12	(1, 200)	50.1667	71.5616	142.65
	Average			$\boxed{36.7169}$		

APPENDIX F

DATA ANALYSIS – UNIT PRICE CONTRACTS

Item	Factor	WEIGHTING STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	7	(3, 7)	6.29	1.4960	23.80
	Number and magnitude of changes	14	(2, 7)	6.20	2.6512	42.76
	Change order administration/management	14	(2, 7)	5.53	2.9488	53.29
	Change in work condition/situation	14	(4, 7)	5.36	1.0818	20.19
	Variations in quantity	14	(2, 7)	6.00	2.9277	48.80
2	**Level of Scope Definition (Overall Weight)**	7	(4, 7)	6.71	0.4880	7.27
	Design or engineering completion	14	(2, 7)	5.93	2.6313	44.35
	Differences in opinion as to scope	14	(2 7)	5.20	2.9326	56.40
	Change (increase or decrease) in scope of work	14	(2, 7)	6.00	2.6726	44.54
	How well responsibilities are defined	14	(2, 7)	5.27	2.7895	52.96
	Thoroughness of risk analysis on design	14	(2, 7)	5.27	3.0111	57.17
	Inconsistent documentation (quality of bid package)	14	(1, 7)	6.40	2.3845	37.26
	Right contractual terms	14	(1, 7)	5.80	2.7045	46.63
3	**Bid (Overall Weight)**	8	(6, 7)	5.38	0.9161	17.04
	Time to bid	14	(3, 7)	5.07	3.0814	60.82
	Clarity of request for bids	14	(1, 7)	5.53	2.7482	49.67
	Mistakes in contractor's or subcontractor's bid	14	(2, 7)	5.27	2.7377	51.98
	Omissions by bidder	14	(2, 7)	5.00	2.9520	59.04
	Completeness of bid package	14	(2, 7)	5.80	2.8335	48.85
	Thoroughness of pre-award interview	14	(3, 7)	5.27	3.2175	61.09
	Bid clarification	14	(3, 7)	5.20	3.0048	57.78
4	**Contract Risks (Overall Weight)**	8	(2, 7)	5.38	1.5059	28.02
	Higher contract administration costs	13	(2, 7)	5.29	2.9202	55.25
	Litigious nature of owner (buyer)	13	(2, 7)	5.43	2.5028	46.10
	Litigious nature of contractor or Subcontractor	13	(2, 7)	5.64	2.4995	44.29
	Litigious nature of Designer (Consultant)	13	(2, 7)	5.36	2.6778	49.98
5	**Market Conditions (Overall Weight)**	8	(4, 7)	5.38	1.5059	28.02
	Change in wage rates	14	(3, 7)	5.47	2.7472	50.27
	Change in material prices	14	(2, 7)	5.33	2.7946	52.40
	Quality and availability of work force	14	(4, 7)	6.53	2.3258	35.60

Item	Factor	WEIGHTING STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	8	(3, 6)	4.75	0.8864	18.66
	Job location	14	(2, 7)	5.73	2.7637	48.20
	Contractor's construction management expertise	14	(4, 7)	6.33	2.3805	37.59
	Owner's construction management expertise	14	(1, 7)	5.60	2.7980	49.96
	Risk allocation to the right party	14	(1, 7)	5.57	2.8278	51.11
	Whether bidder has assessed the difficulty of the work correctly or not	14	(4, 7)	6.07	2.6447	43.56
7	**Others/Performance (Overall Weight)**	8	(5, 7)	5.63	1.9955	35.48
	Rework (Due to lower quality by contactor or subcontractor)	14	(2, 7)	5.60	2.9472	52.63
	Rework due to late changes by owner or designer	14	(3, 7)	6.60	2.3845	36.13
	Failing to meet specifications due to interpretation differences	14	(3, 7)	6.00	2.5071	41.79
	Owner's influence on contractor or subcontractor and thus affecting schedule	13	(3, 7)	6.14	2.4450	39.80
	Effect of site productivity	14	(1, 7)	6.20	2.8335	45.70
	Field supervision costs	13	(3, 7)	6.00	2.4495	40.82

IMPACT UNDER PERFECT CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(-20, 10)	-2.0000	9.0079	450.40
	Change order administration/management	14	(-5, 2)	0.4000	4.0673	1016.82
	Change in work condition/situation	14	(-20, 5)	-0.6000	7.4431	1240.52
	Variations in quantity	14	(-80, 5)	-5.3077	22.8889	431.24
	Average			**-1.8769**		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	13	(-15, 5)	-0.5714	7.3664	1289.12
	Differences in opinion as to scope	13	(-10, 5)	-0.0714	6.1702	8638.29
	Change (increase or decrease) in scope of work	13	(-80, 10)	-7.7143	23.7404	307.75
	How well responsibilities are defined	13	(-20, 5)	-2.3571	10.4558	443.58
	Thoroughness of risk analysis on design	13	(-20, 5)	-2.3571	9.4349	400.27
	Inconsistent documentation (quality of bid package)	13	(-20, 15)	-0.9286	10.6444	1146.31
	Right contractual terms	13	(-30, 5)	-2.7143	12.5785	463.42
	Average			**-2.3878**		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(-20, 5)	-1.5714	7.4287	472.74
	Clarity of request for bids	13	(-15, 5)	-1.9286	6.9334	359.51
	Mistakes in contractor's or subcontractor's bid	13	(-5, 5)	0.3571	4.5676	1278.92
	Omissions by bidder	13	(-5, 5)	0.9286	4.0661	437.89
	Completeness of bid package	13	(-20, 5)	-1.2143	7.3712	607.04
	Thoroughness of pre-award interview	13	(-15, 5)	-1.9286	7.2054	373.61
	Bid clarification	12	(-15, 5)	0.0769	5.7946	7532.93
	Average			**-0.7543**		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(-15, 5)	0.4615	5.7824	1252.85
	Litigious nature of owner (buyer)	13	(-5, 10)	1.4286	4.9570	346.99
	Litigious nature of contractor or Subcontractor	12	(-1, 10)	2.0000	4.2622	213.11
	Litigious nature of Designer (Consultant)	12	(-0, 10)	2.2308	4.1664	186.77
	Average			**1.5302**		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	12	(-2, 6)	2.6154	3.9272	150.16
	Change in material prices	12	(-5, 5)	0.7692	4.4936	584.17
	Quality and availability of work force	12	(-10, 10)	-0.1538	7.0810	4602.67
	Average			**2.0000**		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(-10, 1)	0.3077	5.9355	1929.05
	Contractor's construction management expertise	13	(-15, 12)	-2.0714	8.6065	415.49
	Owner's construction management expertise	13	(-25, 15)	-2.6429	10.4190	394.23
	Risk allocation to the right party	12	(-10, 12)	-0.6154	7.0064	1138.54
	Whether bidder has assessed the difficulty of the work correctly or not	12	(-10, 12)	-0.9231	6.7880	735.37
	Average			-1.1890		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(-3, 3)	1.1429	3.6555	319.86
	Rework due to late changes by owner or designer	13	(-3, 5)	1.8571	4.0165	216.27
	Failing to meet specifications due to interpretation differences	13	(-10, 3)	-0.5714	5.5569	972.46
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(-5, 15)	3.0000	5.4924	183.08
	Effect of site productivity	13	(-10, 25)	5.5714	10.0439	180.27
	Field supervision costs	12	(-10, 5)	0.9231	4.8727	527.88
	Average			1.9872		

IMPACT UNDER LIKELY CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(0, 20)	12.4000	7.3853	59.56
	Change order administration/management	14	(0, 20)	7.6667	7.5750	98.80
	Change in work condition/situation	14	(0, 25)	8.4667	5.8903	69.57
	Variations in quantity	13	(0, 25)	9.2143	7.9244	86.00
	Average			$\boxed{9.4369}$		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	12	(-5, 30)	12.0769	10.2994	85.28
	Differences in opinion as to scope	13	(0, 20)	703571	5.8652	79.72
	Change (increase or decrease) in scope of work	12	(0, 25)	12.8462	8.6202	67.10
	How well responsibilities are defined	12	(0, 22)	5.7692	705736	131.28
	Thoroughness of risk analysis on design	13	(-5, 20)	7.4286	8.4827	114.19
	Inconsistent documentation (quality of bid package)	13	(0, 20)	10.7857	8.8594	82.14
	Right contractual terms	13	(0, 20)	6.28557	6.6498	105.79
	Average			$\boxed{8.9356}$		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	14	(-2, 20)	4.6429	6.2216	134.00
	Clarity of request for bids	14	(-5, 15)	5.2857	5.9669	112.89
	Mistakes in contractor's or subcontractor's bid	14	(-5, 10)	4.8571	4.9901	102.74
	Omissions by bidder	14	(-3, 20)	6.5000	7.0575	108.58
	Completeness of bid package	14	(0, 25)	8.5714	7.8418	91.49
	Thoroughness of pre-award interview	14	(-5, 5)	1.7857	4.2820	239.79
	Bid clarification	13	(-5, 10)	3.6154	5.1241	141.73
	Average			$\boxed{5.0369}$		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(-5, 20)	6.2308	8.1154	130.25
	Litigious nature of owner (buyer)	12	(0, 15)	4.2308	4.9523	117.06
	Litigious nature of contractor or Subcontractor	12	(0, 15)	6.0769	4.4993	74.04
	Litigious nature of Designer (Consultant)	12	(0, 20)	4.8462	5.8998	121.74
	Average			$\boxed{5.3462}$		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	12	(0, 15)	6.9231	4.5178	65.26
	Change in material prices	12	(0, 15)	6.0769	4.4434	73.12
	Quality and availability of work force	12	(0, 15)	7.1539	4.3560	60.89
	Average			$\boxed{13.1154}$		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(0, 25)	7.0769	7.2510	102.46
	Contractor's construction management expertise	13	(-7, 15)	3.1429	7.1453	227.35
	Owner's construction management expertise	13	(-3, 20)	4.0000	6.3124	157.81
	Risk allocation to the right party	12	(-10, 20)	3.7692	7.2704	192.89
	Whether bidder has assessed the difficulty of the work correctly or not	12	(0, 20)	5.3846	6.7767	125.85
	Average			$\boxed{4.6747}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(0, 25)	7.3571	8.1770	111.14
	Rework due to late changes by owner or designer	13	(0, 40)	11.8571	10.4134	87.82
	Failing to meet specifications due to interpretation differences	13	(0, 10)	4.2143	3.7040	87.89
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(0, 20)	7.3846	7.3205	99.13
	Effect of site productivity	13	(0, 50)	12.6429	17.3985	137.62
	Field supervision costs	12	(0, 10)	6.6154	4.7529	71.85
	Average			$\boxed{8.3452}$		

IMPACT UNDER OUTRAGEOUS CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(30, 300)	114.2000	93.6454	82.00
	Change order administration/management	14	(2, 300)	76.0667	98.5955	129.62
	Change in work condition/situation	14	(5, 200)	65.1333	63.7897	97.94
	Variations in quantity	13	(1, 200)	67.5714	59.2527	87.69
	Average			80.7429		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	12	(5, 300)	98.6154	111.7732	113.34
	Differences in opinion as to scope	13	(0, 200)	37.4286	53.2176	142.18
	Change (increase or decrease) in scope of work	12	(7, 200)	92.2308	72.4617	78.57
	How well responsibilities are defined	12	(2, 150)	51.7692	50.0819	96.74
	Thoroughness of risk analysis on design	13	(1, 200)	49.0000	61.0233	124.54
	Inconsistent documentation (quality of bid package)	13	(2, 150)	42.2143	42.1210	99.78
	Right contractual terms	13	(2, 200)	36.7143	53.4882	145.69
	Average			58.2818		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(1, 95)	26.7143	26.6990	99.94
	Clarity of request for bids	13	(1, 50)	19.7857	16.4044	82.91
	Mistakes in contractor's or subcontractor's bid	13	(1, 100)	22.9286	27.0112	117.81
	Omissions by bidder	13	(1, 200)	37.2857	54.0006	144.83
	Completeness of bid package	13	(1, 200)	34.6429	54.1303	156.25
	Thoroughness of pre-award interview	13	(0, 50)	12.8571	16.6496	129.50
	Bid clarification	12	(1, 50)	17.3846	15.8773	91.33
	Average			24.5141		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(0, 50)	17.8462	19.3470	108.41
	Litigious nature of owner (buyer)	12	(0, 200)	32.6923	55.1700	168.76
	Litigious nature of contractor or Subcontractor	12	(5, 200)	39.9231	52.6964	131.99
	Litigious nature of Designer (Consultant)	12	(2, 200	31.5385	53.2002	168.68
	Average			30.5000		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	12	(5, 200)	29.3846	54.4909	185.44
	Change in material prices	12	(1, 200)	29.3846	53.4642	181.95
	Quality and availability of work force	12	(5, 200	48.4615	69.1479	142.69
	Average			68.3077		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(1, 100)	30.4615	35.4015	116.22
	Contractor's construction management expertise	13	(6, 100)	34.5714	36.5297	105.66
	Owner's construction management expertise	13	(2, 100	31.6429	33.8199	106.88
	Risk allocation to the right party	12	(5, 100)	30.2308	27.1820	89.91
	Whether bidder has assessed the difficulty of the work correctly or not	12	(4, 100	30.3846	26.6913	87.84
	Average			$\boxed{31.4582}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(2, 125)	32.4286	42.1914	130.11
	Rework due to late changes by owner or designer	13	(2, 125	39.1429	39.1366	99.98
	Failing to meet specifications due to interpretation differences	13	(3, 50)	16.8571	11.4345	67.83
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(2, 50	23.2308	16.9959	73.16
	Effect of site productivity	12	(9, 200)	47.6429	53.9923	113.33
	Field supervision costs	12	(1, 200	46.0769	70.0482	152.02
	Average			$\boxed{34.2299}$		

APPENDIX G

DATA ANALYSIS – COST PLUS CONTRACTS

Item	Factor	WEIGHTING STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	7	(4, 7)	6.43	1.1339	17.64
	Number and magnitude of changes	14	(3, 7)	6.33	2.5542	40.33
	Change order administration/management	14	(2, 7)	5.53	2.8502	51.51
	Change in work condition/situation	14	(3, 7)	5.93	2.4919	42.00
	Variations in quantity	14	(1, 7)	6.07	2.9391	48.45
2	**Level of Scope Definition (Overall Weight)**	7	(6, 7)	6.71	0.4880	7.27
	Design or engineering completion	14	(1, 7)	6.00	2.7516	45.86
	Differences in opinion as to scope	14	(1, 6)	4.80	2.9081	60.59
	Change (increase or decrease) in scope of work	14	(2, 7)	5.87	2.6956	45.95
	How well responsibilities are defined	14	(3, 7)	5.47	2.7482	50.27
	Thoroughness of risk analysis on design	14	(2, 7)	5.60	2.9713	53.06
	Inconsistent documentation (quality of bid package)	14	(1, 7)	6.13	2.8752	46.88
	Right contractual terms	14	(1, 7)	5.53	2.9968	54.16
3	**Bid (Overall Weight)**	8	(4, 7)	5.25	0.8864	16.88
	Time to bid	14	(2, 7)	4.73	3.0582	64.61
	Clarity of request for bids	14	(2,7)	5.13	2.7740	54.04
	Mistakes in contractor's or subcontractor's bid	14	(1, 7)	5.20	2.9809	57.32
	Omissions by bidder	14	(2, 7)	4.93	2.9391	59.58
	Completeness of bid package	14	(2, 7)	5.93	2.8149	47.44
	Thoroughness of pre-award interview	14	(1, 7)	5.07	3.1728	62.62
	Bid clarification	14	(1, 7)	5.07	3.0347	59.90
4	**Contract Risks (Overall Weight)**	8	(2, 7)	5.38	1.5059	28.02
	Higher contract administration costs	13	(1, 7)	5.43	2.9013	53.45
	Litigious nature of owner (buyer)	13	(2, 7)	5.43	2.5634	47.22
	Litigious nature of contractor or Subcontractor	13	(2, 7)	5.71	2.4940	43.64
	Litigious nature of Designer (Consultant)	13	(1, 7)	5.21	2.8603	54.86
5	**Market Conditions (Overall Weight)**	8	(3, 7)	5.88	1.4577	24.81
	Change in wage rates	14	(3, 7)	5.93	2.5764	43.42
	Change in material prices	14	(3, 7)	5.93	2.5204	42.48
	Quality and availability of work force	14	(5, 7)	6.80	2.1448	31.54

Item	Factor	WEIGHTING STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	8	(3, 7)	5.75	1.3887	24.15
	Job location	14	(2, 7)	6.20	2.5967	41.88
	Contractor's construction management expertise	14	(2, 7)	6.80	2.3664	34.80
	Owner's construction management expertise	14	(5, 7)	6.67	2.2254	33.38
	Risk allocation to the right party	13	(2, 7)	6.00	2.3534	39.22
	Whether bidder has assessed the difficulty of the work correctly or not	13	(2, 7)	6.36	2.4054	37.84
7	**Others/Performance (Overall Weight)**	8	(1, 7)	6.00	2.0702	34.50
	Rework (Due to lower quality by contactor or subcontractor)	14	(4, 7)	6.53	2.3258	35.60
	Rework due to late changes by owner or designer	14	(3, 7)	6.53	2.4746	37.88
	Failing to meet specifications due to interpretation differences	14	(3, 7)	6.20	2.5128	40.53
	Owner's influence on contractor or subcontractor and thus affecting schedule	13	(2, 7)	6.07	2.5560	42.10
	Effect of site productivity	14	(1, 7)	6.67	2.5542	38.31
	Field supervision costs	13	(4, 7)	6.43	2.1738	33.81

IMPACT UNDER PERFECT CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(-20, 25)	-0.0667	12.8978	19337.03
	Change order administration/management	14	(-10, 20)	0.8667	7.7632	895.75
	Change in work condition/situation	14	(-20, 15)	-0.6000	10.2665	1711.08
	Variations in quantity	13	(-10, 5)	0.2857	6.3419	2219.67
	Average			**0.1214**		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	13	(-20, 5)	-2.7857	8.6129	309.18
	Differences in opinion as to scope	13	(-10, 5)	-0.5000	5.9840	1196.79
	Change (increase or decrease) in scope of work	13	(-50, 10)	-4.7857	15.8074	330.30
	How well responsibilities are defined	13	(-30, 5)	-3.5000	10.9246	312.13
	Thoroughness of risk analysis on design	13	(-20, 5)	-3.7143	10.0033	269.32
	Inconsistent documentation (quality of bid package)	13	(-20, 6)	-1.5000	10.0900	672.67
	Right contractual terms	13	(-30, 5)	-5.1429	14.3412	278.86
	Average			**-3.1327**		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(-20, 5)	-1.2143	7.3712	607.04
	Clarity of request for bids	13	(-15, 5)	-0.7143	6.4502	903.02
	Mistakes in contractor's or subcontractor's bid	13	(-20, 5)	-0.1429	6.8034	4762.35
	Omissions by bidder	13	(-20, 5)	-0.1429	6.8034	4762.35
	Completeness of bid package	13	(-20, 5)	-3.2857	9.5308	290.07
	Thoroughness of pre-award interview	13	(-20, 5)	-2.5714	8.5008	330.59
	Bid clarification	13	(-15, 5)	-0.7143	6.3540	889.56
	Average			**-1.2551**		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	13	(-15, 5)	1.3077	6.2767	479.99
	Litigious nature of owner (buyer)	12	(-10, 5)	0.6923	5.1378	742.13
	Litigious nature of contractor or Subcontractor	12	(-1, 5)	2.0000	3.7417	187.08
	Litigious nature of Designer (Consultant)	12	(-0, 10)	2.6154	4.1741	159.60
	Average			**1.6539**		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(-5, 20)	3.0000	6.7596	225.32
	Change in material prices	13	(-5, 15)	0.9286	6.1702	664.48
	Quality and availability of work force	13	(-10, 25)	1.5714	8.6444	550.10
	Average			**3.2136**		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(-10, 5)	1.0769	6.1841	574.24
	Contractor's construction management expertise	13	(-20,15)	-2.8571	9.4613	331.15
	Owner's construction management expertise	13	(-30, 20)	-2.5714	11.4872	446.72
	Risk allocation to the right party	12	(-10, 15)	-0.3846	7.4893	1947.22
	Whether bidder has assessed the difficulty of the work correctly or not	12	(-10, 15)	0.0769	7.3310	9530.30
	Average			-0.9319		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(-3, 5)	1.6429	-4.1064	249.96
	Rework due to late changes by owner or designer	13	(-1,10)	2.6429	4.7654	180.31
	Failing to meet specifications due to interpretation differences	13	(-10, 8)	0.3571	6.2463	1748.97
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(-5, 6)	2.0769	4.7865	230.46
	Effect of site productivity	13	(-10,25)	4.5714	10.8749	237.89
	Field supervision costs	12	(-2, 20)	2.6923	6.3690	236.56
	Average			2.3306		

IMPACT UNDER LIKELY CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	13	(5, 30)	13.7143	7.7403	56.44
	Change order administration/management	13	(1, 20)	11.0714	7.3219	66.13
	Change in work condition/situation	13	(3, 25)	12.5000	7.2404	57.92
	Variations in quantity	13	(0, 50)	14.3571	11.9718	83.39
	Average			12.9107		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	13	(-5, 75)	16.6429	19.1978	115.35
	Differences in opinion as to scope	13	(0, 50)	8.4286	12.8225	152.13
	Change (increase or decrease) in scope of work	12	(0, 50)	14.6154	13.0735	89.45
	How well responsibilities are defined	12	(0, 50)	8.1539	13.9574	171.18
	Thoroughness of risk analysis on design	13	(-5, 40)	9.5000	12.2144	128.57
	Inconsistent documentation (quality of bid package)	13	(-5, 50)	10.4286	12.7141	121.92
	Right contractual terms	13	(0, 30)	6.7857	8.5591	126.13
	Average			10.6507		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(0, 25)	6.0714	7.8394	129.12
	Clarity of request for bids	13	(-5, 20)	6.6429	7.2812	109.61
	Mistakes in contractor's or subcontractor's bid	13	(-5, 10)	5.1429	5.0514	98.22
	Omissions by bidder	13	(-5, 20)	6.3571	7.4173	116.68
	Completeness of bid package	13	(-5, 25)	7.9286	8.7307	110.12
	Thoroughness of pre-award interview	13	(-5, 10)	2.50000	4.5868	183.47
	Bid clarification	13	(-5, 10)	3.5000	4.8793	139.41
	Average			5.4490		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(-5, 20)	8.3077	8.4596	101.83
	Litigious nature of owner (buyer)	12	(0, 15)	4.0769	5.0574	124.05
	Litigious nature of contractor or Subcontractor	12	(0, 15)	7.2308	5.1503	71.23
	Litigious nature of Designer (Consultant)	12	(0, 20)	5.8462	5.7713	98.72
	Average			6.3654		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(0, 30)	8.6429	8.4998	98.35
	Change in material prices	13	(0, 25)	7.3571	6.7551	91.82
	Quality and availability of work force	13	(0, 40)	10.3571	10.1724	98.22
	Average			16.8571		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(0, 25)	7.1539	7.4927	104.74
	Contractor's construction management expertise	13	(-5, 17)	5.0000	6.8837	137.67
	Owner's construction management expertise	13	(-10, 30)	5.7143	9.3185	163.07
	Risk allocation to the right party	12	(-10, 50)	7.5385	14.6436	194.25
	Whether bidder has assessed the difficulty of the work correctly or not	12	(-10, 20)	4.4615	7.4790	167.63
	Average			$\boxed{5.9736}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(0, 50)	11.3571	13.5227	119.07
	Rework due to late changes by owner or designer	13	(0, 60)	17.0714	17.4023	101.94
	Failing to meet specifications due to interpretation differences	13	(0, 15)	6.5714	5.1248	77.99
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(0, 30)	9.8462	8.6780	88.14
	Effect of site productivity	13	(0, 100)	18.7857	26.5828	141.51
	Field supervision costs	12	(0, 20)	9.3077	6.7871	72.92
	Average			$\boxed{12.1566}$		

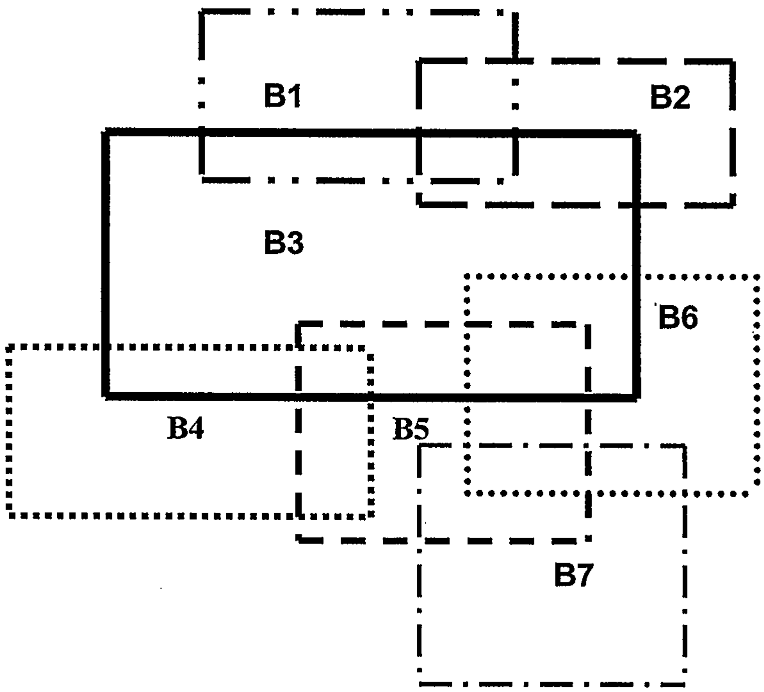
IMPACT UNDER OUTRAGEOUS CONDITIONS

Item	Factor	IMPACT (%) STATISTICS				
		# of Res.	Range	Mean	STDEV	CoV
1	**Change Order (Overall Weight)**	-	-	-	-	-
	Number and magnitude of changes	14	(15, 500)	156.6000	125.5182	80.15
	Change order administration/management	14	(2, 300)	85.7333	86.8895	101.35
	Change in work condition/situation	14	(7, 200)	76.2667	62.1547	81.50
	Variations in quantity	13	(1, 200)	72.7857	63.6253	87.41
	Average			97.8464		
2	**Level of Scope Definition (Overall Weight)**	-	-	-	-	-
	Design or engineering completion	13	(5, 300)	102.1429	101.1753	99.05
	Differences in opinion as to scope	13	(0, 100)	36.6429	37.2323	101.61
	Change (increase or decrease) in scope of work	12	(5, 200)	91.3077	70.5259	77.24
	How well responsibilities are defined	12	(4, 100)	42.3846	40.8055	96.27
	Thoroughness of risk analysis on design	13	(3, 200)	56.7857	69.0453	121.59
	Inconsistent documentation (quality of bid package)	13	(4, 150)	40.1429	41.6946	103.87
	Right contractual terms	13	(2, 150)	40.7143	45.4388	111.60
	Average			58.5887		
3	**Bid (Overall Weight)**	-	-	-	-	-
	Time to bid	13	(0, 100)	28.3571	33.8994	119.54
	Clarity of request for bids	13	(5, 100)	23.6429	25.5813	108.20
	Mistakes in contractor's or subcontractor's bid	13	(2, 100)	24.5714	26.8349	109.21
	Omissions by bidder	13	(2, 100)	26.6429	34.2717	128.63
	Completeness of bid package	13	(2, 200)	38.8571	57.9295	149.08
	Thoroughness of pre-award interview	13	(0, 100)	15.6429	27.2724	174.34
	Bid clarification	13	(0, 50)	15.5000	16.2090	104.57
	Average			24.7449		
4	**Contract Risks (Overall Weight)**	-	-	-	-	-
	Higher contract administration costs	12	(0, 50)	20.7692	18.5299	89.22
	Litigious nature of owner (buyer)	12	(0, 200)	29.0769	55.9947	192.57
	Litigious nature of contractor or Subcontractor	12	(7, 200)	39.9231	52.6173	131.80
	Litigious nature of Designer (Consultant)	12	(2, 75)	32.9231	54.3714	165.15
	Average			30.6731		
5	**Market Conditions (Overall Weight)**	-	-	-	-	-
	Change in wage rates	13	(5, 200)	32.0000	53.9344	168.55
	Change in material prices	13	(5, 200)	29.0714	50.5302	173.81
	Quality and availability of work force	13	(10, 200)	51.7143	67.1387	129.83
	Average			70.9286		

Item	Factor	IMPACT (%) STATISTICS (Cont'd)				
		# of Res.	Range	Mean	STDEV	CoV
6	**Risk Management Issues (Overall Weight)**	-	-	-	-	-
	Job location	12	(3, 150)	34.5385	43.9329	127.20
	Contractor's construction management expertise	13	(0, 200)	37.0714	52.9331	142.79
	Owner's construction management expertise	13	(3, 200)	42.5714	52.8098	124.05
	Risk allocation to the right party	12	(1, 200)	32.0000	52.8141	165.04
	Whether bidder has assessed the difficulty of the work correctly or not	12	(2, 200)	51.2308	58.4539	114.10
	Average			$\boxed{39.4824}$		
7	**Others/Performance (Overall Weight)**	-	-	-	-	-
	Rework (Due to lower quality by contactor or subcontractor)	13	(3, 150)	43.6429	48.3872	110.87
	Rework due to late changes by owner or designer	13	(1, 125)	47.0000	44.1152	93.86
	Failing to meet specifications due to interpretation differences	13	(2, 50)	23.1429	17.2442	74.51
	Owner's influence on contractor or subcontractor and thus affecting schedule	12	(0, 125)	32.1539	34.0094	105.77
	Effect of site productivity	13	(14, 200)	63.0000	63.3209	100.51
	Field supervision costs	12	(2, 200)	39.3077	54.9703	139.85
	Average			$\boxed{41.3745}$		

APPENDIX H – COST FACTOR OVERLAP VENN DIAGRAMS

H1: LEVEL OF SCOPE DEFINITION



B1 – Right contractual terms

B2 – Risk analysis on design

B3 – Design completeness

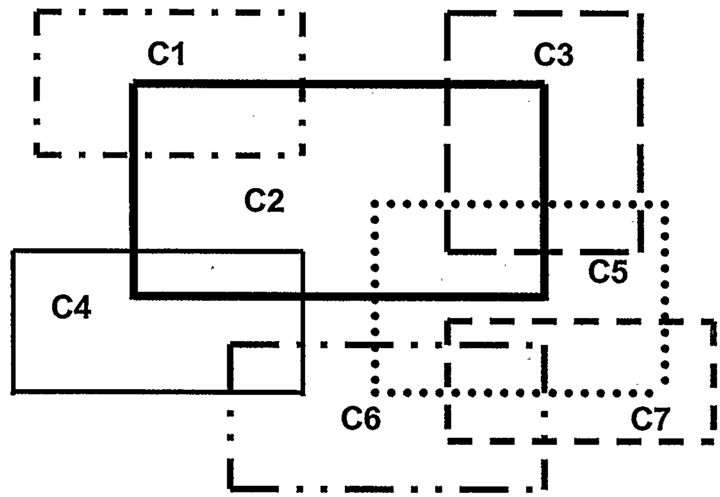
B4 – How well responsibilities are defined

B5 – Change in scope of work

B6 – Differences in opinion as to scope

B7 – Inconsistent documentation

H2: BID PROCESS



C1 – Ommissions by bidder

C2 – Time to bid

C3 – Mistakes in vendors bid

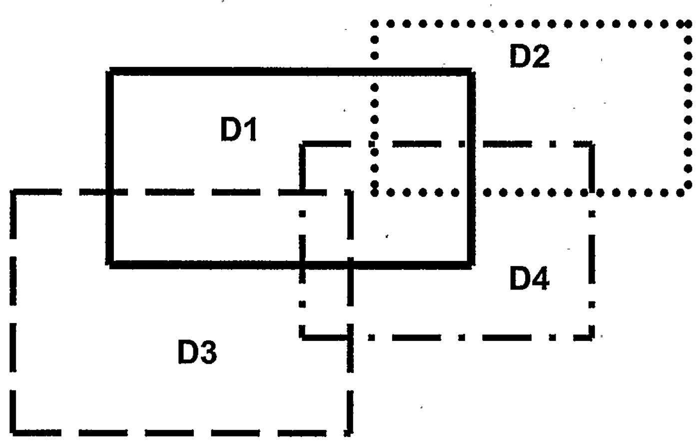
C4 – Completeness of bid package

C5 – Clarity of request for bids

C6 – Bid Clarification

C7 – Pre-award interview

H3: CONTRACT RISK



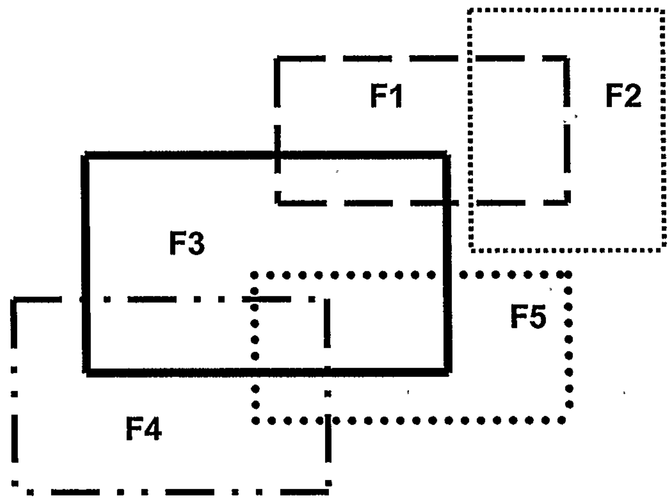
D1 – Higher contract administration cost

D2 – Litigious nature of contractor

D3 – Litigious nature of designer

D4 – Litigious nature of owner

H4: RISK MANAGEMENT ISSUES



F1 – Risk allocation to the right party

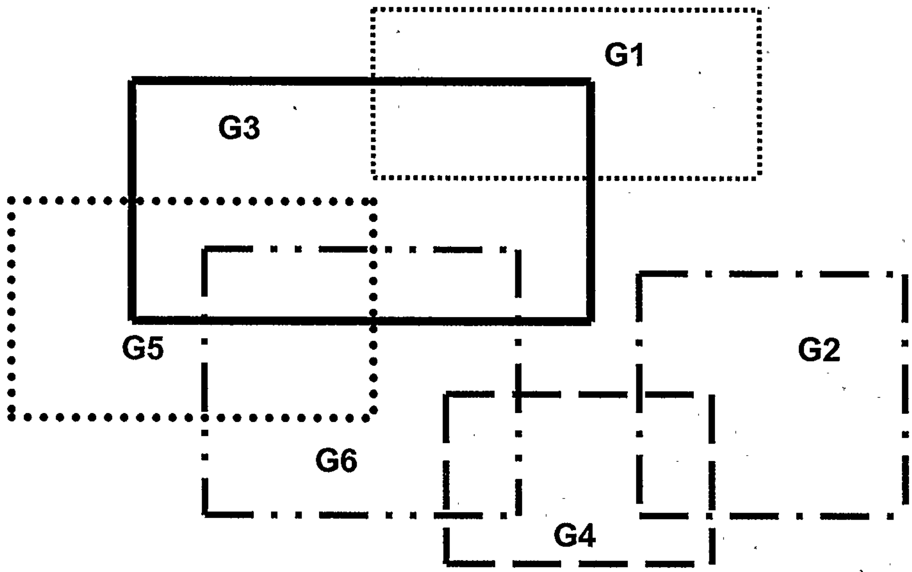
F2 – Bidder assessing difficulty of the work correctly or not

F3 – Job location

F4 – Owner's construction management expertise

F5 – Contractor's construction management expertise

H5: PERFORMANCE



G1 – Rework due to lower quality by vendor

G2 – Rework due to late changes by owner or designer

G3 – Failing to meet specifications due to interpretation differences

G4 – Owner's influence on vendor, thus affecting schedule

G5 – Effect of site productivity

G6 – Field supervision costs