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Innovative Contracting Prequalification/Selecion Model using Analytical Hierarchy Process (AHP)

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INNOVATIVE CONTRACTING PREQUALIFICATION/SELECION MODEL USING ANALYTICAL HIERARCHY PROCESS (AHP)

by

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Design-Build, Cost-Plus-Time, and warranty are the three innovative contracting methods that the Federal Highway Administration (FHWA) decided to fund. FHWA allowed the usage of these methods in federally funded projects if this will result in reducing time, improving quality, and saving tax payers' money. Prequalification is recognized as the best way of assuring that contractors do have the required qualifications to deliver projects successfully. Prequalification is even more critical when low-bid selection method is used with any of the innovative contracting, since incompetent contractors may get awarded for low-bids that are not based on valid assumptions.

This study presents a low-bid prequalification model for projects delivered using any of the three innovative contracting methods. For each innovative method, there are two-step prequalification criteria applied to the contractors before they reach the final bidding stage. Technical bids are used to gather the criteria-related data from the contractor and sense his understanding of the owners' needs. The Analytical Hierarchy Process (AHP) is used as a tool to help in assigning weights to the established criteria and ranking contractors accordingly.

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Chapter One

Introduction

1.1. Introduction

Design-Build, Cost-Plus-Time, and Warranty are the three innovative contracting methods that the Federal Highway Administration (FHWA) decided to fund. The FHWA allowed the usage of these methods in federally funded projects on the condition that they will result in reducing time, improving quality, and saving tax payers' money. These innovative methods have gone through several years of testing and modification under the FHWA Special Experimental Project No. 14 (SEP-14 - Innovative Contracting) before they were considered operational. Bidding procedures, materials control, quality considerations, and insurance and surety issues were the major issues investigated for these methods (FHWA, 2001). SEP-14 also investigated workable risk assignments between contractors and owners (TRB, 1991).

The nature of three innovative methods and the projects that they deliver present tough challenges for contractors and owners. Quality, schedule, technical, and financial challenges accompany these projects because of their complexity and/or short time to be accomplished. Contractors should be capable and experienced enough in order to successfully deliver projects. Otherwise, failure of contractors on the project or organizational level is very high. Prequalification of contractors dramatically reduces this risk and assures that final bidders will submit realistic bids that are based on true assumptions and come from profound experience (Russell, 1996).

Prequalification here requires establishing project specific prequalification criteria. Then, the data that is related to these data are collected. Technical bids are an efficient way of collecting up to date information about the contractor. They also reveal his understanding of the owner's needs and his ability to transfer his ideas into conceptual construction and management plans. Eventually, the owner makes his decision and selects the competent contractors.

For public agencies, decision-making should be systematic and justifiable. It also requires handling the many issues that the prequalification criteria investigate. These criteria contain qualitative and quantitative parameters. Applying the Analytical Hierarchy Process (AHP) as multi-criteria decision-making presents the justifiable solution. The AHP has been used in several applications in project management and is known for its capability to accept qualitative and quantitative judgments.

1.2. Research Objectives

This research presents a model to prequalify contractors who want to bid on public projects delivered under any of the three innovative contracting methods: Design-Build, Cost- Plus-Time, and Warranty. The final selection method is still low-cost bidding because it is the most favorable within the public sector and there are many limitations on using other selection methods. The model is supposed to be easy to use and flexible. It also has to achieve fairness and be justifiable. In order to do so, the study will try to establish simple prequalification criteria that match each of the prequalification processes. Then, it will employ an easy software supported decision-making tool, which is the AHP.

One major goal of this study is to investigate the compatibility of the AHP to prequalification. The development of the qualification criteria involves assigning importance weight for each criterion. The AHP is supposed to be capable of generating these weights after the criteria are compared to each other. After collecting data about contractors and making comparisons between them, AHP will use these weights in ranking contractors. The study will illustrate the easiness of applying AHP software to perform these operations.

1.3. Research Methodology

The research goes through the following steps to fulfill its objective:

1. Identify the three innovative contracting methods through reviewing literature. This is necessary to enable recognizing the characteristics of each method to determine the specific qualifications of the contractors who will be of greater potential to succeed in delivering the projects.
2. Study the current prequalification practices through reviewing literature and prequalification procedures used by some public agencies. In order to do so, several prequalification questionnaires and regulations of departments of transportation, city councils, and other public agencies were studied. Phone interviews were conducted with prequalification personnel to know the philosophy behind the procedures they follow.

3. Explore the potential of the AHP to serve as a tool for prequalification decision making. This was done by reviewing the current applications of AHP in project management. The mathematical operations of the process, building hierarchies, and measuring consistency were studied.
4. Develop a contractors' prequalification model that consists of several stages and includes two-step prequalification criteria for each of the innovative contracting methods.
5. Apply the AHP as a decision making tool for developing and assigning weights for each criterion. This was achieved by utilizing the expertise of prequalification engineer. Then, the weights will be used and the judgments obtained from real-life prequalification examples to rank the contractors.
6. Develop conclusions and recommendations, based on the analysis of the case studies, the literature review, and the results of this study.

1.4. Research Organization

Chapter two introduces the areas that innovation is applied to. It also presents the reasons for which this study considers the mentioned three innovative contracting methods. It gives a brief description of each method and the criteria for selecting it to deliver a project. The barriers that prevent from introducing innovation to the industry are discussed at the end of the chapter.

Prequalification process is explained in chapter three. The advantages and disadvantages of using this process for owners and contractors are discussed. Then, the prequalification steps are presented and related to the innovative methods. Various numbers of contractor selection methods are presented. A discussion of the reasons for which this study uses AHP and how it differs from current models is made.

Chapter four presents the advantages of AHP and its compatibility to prequalification process. The steps of AHP are explained through an example.

Chapter five presents the developed prequalification model and describes its step and components, while chapter six presents case studies for each on of the innovative methods. Finally, Chapter seven summarizes this study and lists the conclusions, recommendations, contributions, and future research of this study.

Chapter Two

Innovative Contracting

2.1. Introduction

Since 1990, the Federal Highway Agency (FHWA) has been supporting the revision of non-traditional contracting methods through Innovative Contracting Special Experimental Projects NO.14 (SEP-14) (FHWA, 2001). SEP-14 aims to evaluate innovative contracting practices that that might reduce the life cycle cost of projects without causing any negative impacts on the quality of the structure. In collaboration with FHWA, the Transportation Research Board (TRB) and the National Research Agency (NRA) held a conference entitled, "Task Force on Innovative Contracting Practices." This task force held a conference in December of 1991, where over 50 national and international experts on contract administration from both public and private sectors attended a series of sessions and meetings. The recommendations made by this task force are considered as guidelines for all the concerned parties, such as legislatures, experts, researchers, lenders, and even tax payers (WSDOT, 2003).

This task force addressed four major topic areas:

1. Bidding Procedures
2. Materials Control
3. Quality Consideration
4. Insurance and Surety Issues

The experts have discussed procedural issues that prevail, as well as those that encourage innovation and outstanding quality. They have also addressed the fairness of the procedure by which risks are assigned to owners and contractors, since a balanced cost-risk trade-off is an important factor in a project's success. This led them to discuss the effectiveness of penalties and incentives.

The task force agreed that a successful bidding process is a key to the overall success of a project. In order to achieve such success, the task force started to suggest that enhancements be applied to the bidding process. The main issues that were to be addressed by these enhancements are:

1. Risk avoidance
2. Evaluating bids
3. Selection of competent contractors
4. Guarantee a quality product
5. Meet federal and state regulations

This task force also analyzed a questionnaire that was sent two years before to staff construction engineers in each of the 50 states (TRB, 1991). This questionnaire on contracting practices was used to determine the state of the practice used at the time by state highway and transportation agencies. Twenty six contracting methods were listed in the questionnaire without providing any definition, leaving space for state experts to provide their own interpretation according to their experience. The responses showed that states tend to use contracting methods that are accepted and encouraged by FHWA.

These methods are believed to enhance innovation in quality, contractor selection, and bidding processes.

The task force provided many long and short-term recommendations on several topics among them (TRB, 1991):

- "The cost plus time bidding concept should be considered for wider implementation with caveat that appropriate must be in place. However, careful selection of the types of the projects as well as accurate determination of the time value is required. The cost plus time bidding, which represents a variation to traditional lowest initial cost bidding, reflects the additional costs to highway users from inconvenience and delay during construction activities."
- "The potential for use of warranties or guaranties should be investigated with the goal of delineating standards and procedures for maintaining data on highway segments built with warranties."
- "Attention should be given to the use of constructability through encouraging close coordination of all aspects between those who design and who will implement the design. This can be certainly achieved by using Design Build."

Many states experimented with these recommendations. In October 2001, after evaluating the performance of the results, the FHWA had declared the following contracting methods operational (FHWA, 2001):

1. Cost-Plus-Time
2. Lane Rental
3. Warranty Clauses

Operational means that the FHWA does not have to provide conceptual approval for using any of these contracting methods when there is a federally funded project.

It was not until December 2002 that the FHWA published a final rule considering the Design-Build operational. In that rule, it is required to consider Design-Build as an optional innovative method only if it is believed to reduce time or save taxpayer dollars. Recipients of Federal Aid Highway Program funds will be able to use the Design-Build method just as they would use the Design-Bid-Build method. This rule was also approved under the SEP-14 after FHWA, 25 states, and several local public agencies evaluated more than 230 Design-Build projects from the past 10 years (FHWA, 2002). Congress, however, limited the usage of the Design-Build system to the following qualified projects:

1. Greater than $50 million in value
2. Greater than $5 million, Intelligent Transportation System (ITS) projects

These limitations have reduced the frequency of using Design-Build. On the other hand, these projects were interesting to experts and researchers because of their value. Projects that involve this amount of taxpayers' money will put the public agency under significant political and public pressure to ensure that the agency is doing it right (TRB, 1991).

2.2. Project Delivery Systems

Design-Build

Design-Build is a form of project delivery that enables the owner to deal with a single point of responsibility for both design and construction. Instead of the traditional Design-Bid-Build, the owner has a contract with a single entity to design and build the project. The Design-Build entity becomes solely the accountability of the owner in the areas of cost, schedule, and quality. The owner can focus his efforts on defining the scope and needs of the project rather than on coordination between the designer and the builder (Vance, 2001). The Design-Build agency can be a single firm or a joint venture for a particular project. The design-builder can be a consultant who hires a contractor to construct the project as shown in Figure 1. Figure 2 shows the hierarchy when the design-builder is a contractor who hires a consultant to provide the design. These two forms represent a single entity design-builder where either the consultant or the contractor has subcontracted the other. The subcontracted party should also satisfy the public agency or the owner's criteria.

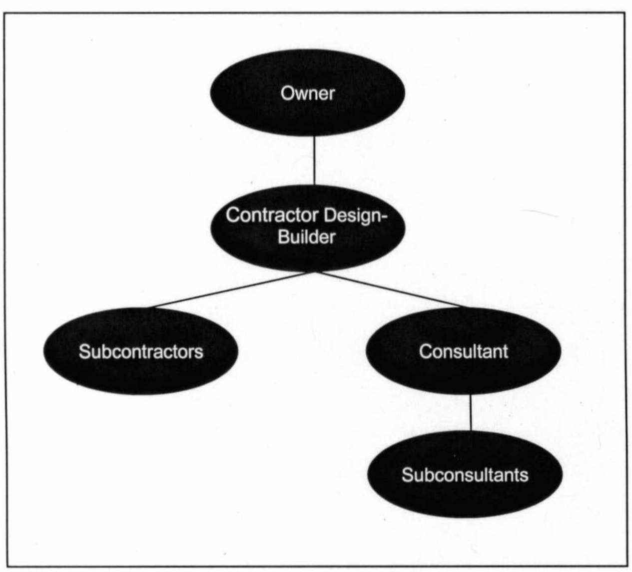

Figure 1: Contractor Led Design Builder

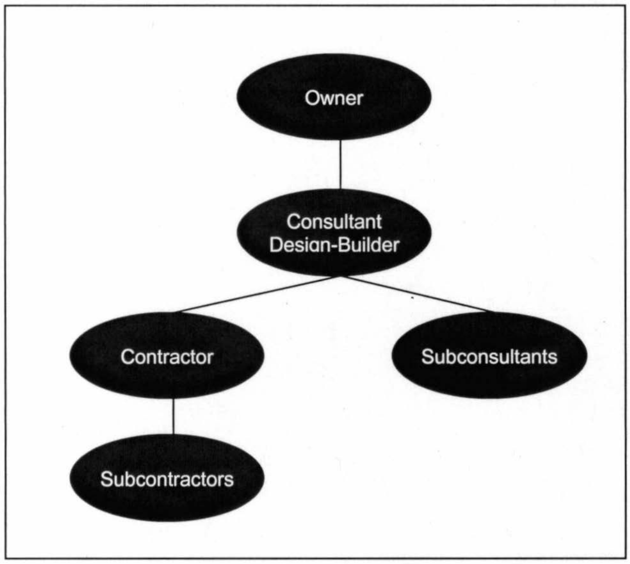

Figure 2: Consultant Led Design-Builder

Dealing with joint ventures is less desirable by public agencies since miscommunication and disputes between the consultant and the subcontractor are more likely. Figure 3 shows the joint venture's structure.

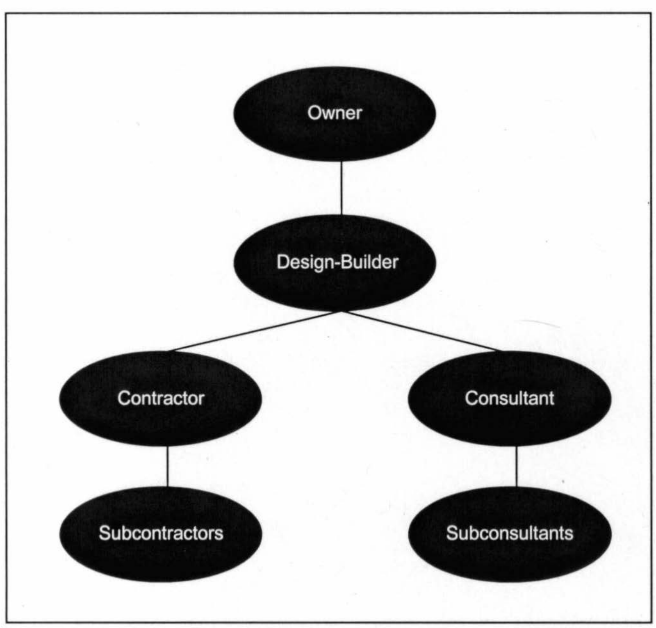

Figure 3: Joint Venture Design Builder

Another form of the Design-Build system is “Bridging.” In this approach, the owner does not want to rely fully on the Design-Build entity in translating his conceptual ideas into design drawings. In other cases, the owner has a long-term relationship with a consultant who does not have the capabilities to carry out large-scale projects, but can produce a preliminary design based on his needs. Then, the owner uses this preliminary design to solicit bids from design-builders to complete the design documentation and construct the project. The Design-Build entity will have the final construction documents prepared by its own consultant (Dorsey, 1997).

For other large infrastructure projects, such as toll roads and bridges, Design-Build-to- Operate can be used. Projects like the Indiana Toll Road and the Washington Bridge in New York are good examples of this contracting method. The owner of these structures is the state, but they are leased to the design-builder. The design-builder collects the toll fee to make his profit. At the same time, he maintains the structure in specified conditions agreed upon in the bidding agreement. At the end of the lease period, owners have several options, which include accepting the completed facility or changing the transfer date (Dorsey, 1997).

Due to the complexity and large work volume of Design-Build projects, selecting a suitable engineering or construction firm under this approach is based on certain key factors (Yates, 1995):

1. Previous experience with similar projects.
2. Outstanding financial status

3. Experienced key personnel
4. Construction capabilities
5. Project management capability
6. Engineering capabilities
7. Quality of project control

Cost-Plus-Time

Cost-Plus-Time bidding is a method of rewarding a contractor for completing a project as quickly as possible. The contract provides a cost for each working day by combining the cost of performing the work with that of its impact on the public to provide the lowest cost to the public.

A+B bidding is a Cost-Plus Time bidding procedure. The low bidder is selected based on a combination of the traditional contract unit price items bid (A) and the time proposed by the bidder to complete the project or a critical portion of the project (B). The time needed to complete the project (B) is assigned a monetary value. This value is commonly known as Road User Cost (RUC), and it is estimated in dollars per day ($/day). This value can range between $1,000/day to $200,000/day (Herbsman, 1995). By multiplying RUC by the number of days, we can determine the (B) component of the bid.

The bidder with the lowest overall combined bid (A+B) is awarded the contract. In the actual contract, the contractor will only be reimbursed for unit items (A). The time allowed to complete the project is set at the bidders' time component (B) (WSDOT, 2002).

Herbsman has surveyed 101 projects in 15 states' Departments of Transportation (DOTs) that are using this method (Herbsman, 1995). He investigated the following questions regarding Cost-Plus-Time:

1. Does the A+B method reduce contract time as compared to the time given to similar projects using traditional bidding method?
2. Have Projects that were bid using A+B method been completed on time?
3. Does a reduced bid time have (part B) have any effect on the cost estimated by contractor (part B)?
4. What types of projects (work type and budget) have been selected by the states to be awarded using the A+B method?

In conventional bidding methods, the time estimated by the state (engineer's time) becomes the official contract time, and in most cases, the actual completion time will be very close to the contract time (Herbsman and Ellis). The study showed, however, that in A+B, 91% of the projects had contractors' bidding time less than the engineer's time. In some states, such as North Carolina, the average time savings on 13 projects was 28%. It can be concluded that the engineer's time is on the high side.

When an incentive was used, 82% of the projects were completed ahead of time, 5% on time, and 12.5% were behind schedule. The highest time savings reached 63%, and the highest overrun was 31%. In some cases, the incentive to finish early was equal to the RUC value for each saved day with no limitation on the number of days. In other projects, the limited number of days or certain percentage of the total budget was not to be exceeded as an incentive.

The experts interviewed in Herbsman's study said that their expertise does not show any increase of cost by contractors even though they are delivering the projects within a shorter time. Unit prices were the same as those used by contractors in conventional bidding. Others believe that A+B contracts may cause an increase in construction costs. On a standard A+B project, a contractor may see an opportunity to reduce the total construction and traffic impacts on neighboring areas, but a shorter duration solution may increase the primary item cost. Whether through acceleration, aggressive management of subcontractors, or specialty equipment, it is likely that the construction price will increase. However, the reduction in impacts would reduce the overall traffic control cost (WSDOT, 2002).

Cost-Plus-Time is mainly used on highway or bridge projects that already exist and require certain projects (WSDOT, 2002):

1. Widening projects where permanent traffic control is to be set up for an extended period of time (Herbsman, 1995)
2. Projects which have multiple activities occurring which don't necessarily have to be done sequentially (Herbsman et al. 2000)
3. Projects where the contractors presence/activities will impact traffic regardless of whether traffic control is set up

4. Projects in which innovative solutions by the contractor are sought (specialty work) which may be beyond designer's expertise (WSDOT, 2002)

Figure 4 illustrates the share of each type according to Herbsman's survey.

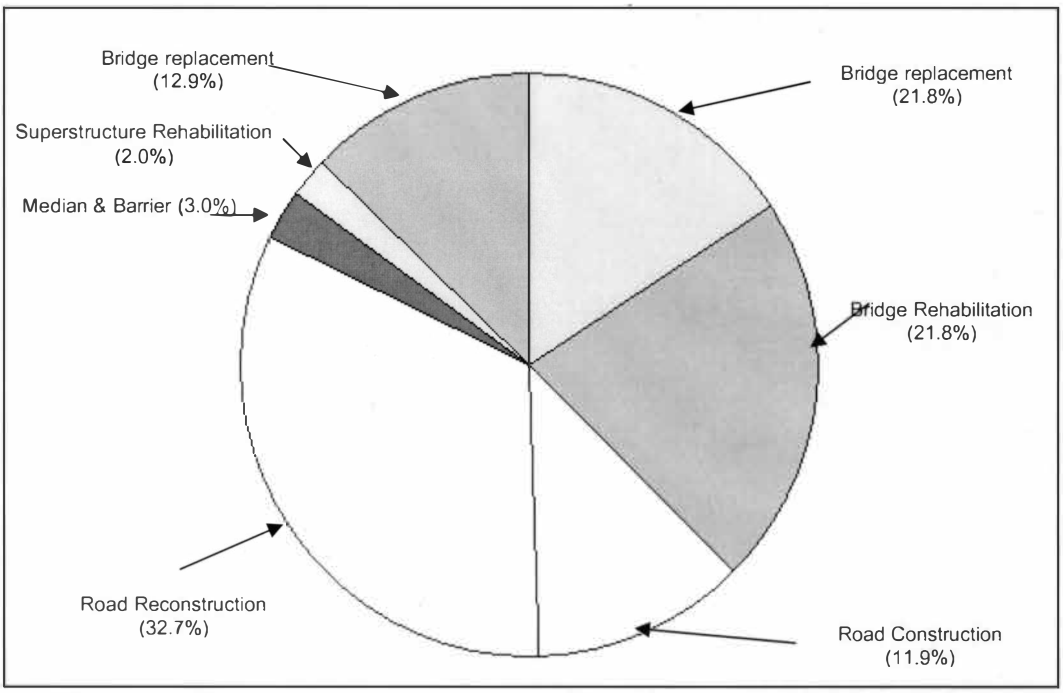

Figure 4: Work Type of Projects that Were Bid Using Cost-Plus-Time

Not all projects that fall under any of these categories should be bid using Cost-Plus- Time. Based on FHWA guidelines, WSDOT adopted the following criteria (WSDOT, 2002):

1. Traffic restrictions, lane closures, or detours are likely to result in significant user costs. The contractual incentive of the time component cannot be readily apparent if the value is too low. On lower volume roads, with acceptable detours, user impacts are not likely to be high enough to justify selecting a higher priced project.

2. Significant impacts to the local community or economy during construction warrant expediting the total length of the project. Some projects, despite their location on lower volume roadways, will have significant impacts on the local economy. In these cases a designer may decide that the potential to minimize the economic impacts justify the additional cost of acceleration.
3. Traffic control staging, utilizing specialized equipment or methods, can be structured to maximize a contractor's ability to reduce the time for completion at a reasonable increase in cost. This potential staging should be one that designers are hesitant to specify as it may reduce competition. For example, one competitor has an established plant adjacent to the project which can make access to the work zone more efficient and thereby potentially shorten the work window. Specifying the use of a sole-source in this instance would likely not provide a competitive price.
4. The project is relatively free of utility conflicts, design uncertainties, right-of-way conflicts, or other issues that may impact the award date or critical project scheduling but remain outside of the contractor's control. Items that are outside of the contractors control but may impact the overall project delivery could make it exceedingly risky for a contractor to guarantee an early delivery.
5. WSDOT seeks a contractor’s expertise to facilitate an early completion. In some cases, expertise within the contracting community may be able to

provide a more efficient solution to a problem. Specialized work and mechanical/electrical projects could potentially fall within this category.

Lane Rental is the practice of charging the contractor a fee for occupying lanes or shoulders during construction. Charges are based on hourly or daily rates and can vary with time of day, amount of traffic, and other measures of the user's cost. These charges are used to encourage the contractor not to work during peak hours to reduce the impact on traffic and neighboring businesses (FHWA, 2001). Similar to Cost-Plus-Time, this incentive can be used for early completion.

Warranty

Warranty is an option practiced by DOTs if the performance on the site warrants it (Schoenfeld, 1998). Using a warranty is totally different than traditional contracting practices where a performance bonds required from the contractor for a sort amount of time; it aims to protect the initial investment of the DOT and encourage innovation and quality improvement. The standard method restrains the contractor with the design, sequence of operations, and materials to be used. The inspection and supervision practiced by the state is stringent. The contractor is a performer and does not bear responsibility for any defects after the project is accepted.

On the other hand, under the new Warranty approach, contractors are given the right to select construction materials, methods, and mix design (Schoenfeld, 1998). These specifications would only describe the performance of the project using certain indicators, which decide if or not a defect occurs (Anderson and Russell, 2001). In other words, it is a form of Performance Based Specifications, one of the innovative contracting practices. In Design-Build-Warranty projects, the contractor also provides a detailed design of the whole project

The contractor should be able to obtain a warranty bond from a surety company. This bond may last for several years and it can be for a single term or a renewable performance bond (Russell, 1999).

In this method, a contractor without a long standing performance in the market will face difficulty obtaining the performance bond, a bond that could last for several years. This situation is unfavorable for surety companies. This is also risky for the state, since the construction company may go out of business at any time. Such a scenario will transfer responsibility to the DOT to take care of a project that they did not design or supervise.

2.3. Barriers to Innovation

The major goal of the bidding process in public projects is to minimize cost and risk. When a public agency contracts for a project, it is subjected to many risks. Avoidance of adverse publicity or political criticism directed at poor performance or unacceptable practices, reduction in safety, construction delays, and legal or other liabilities all influence public contracting practices. This is why it is more comfortable for all parties to deal with known contracting methods rather new methods.

Innovation, at least in the early stages of implementation, does not provide the peace of mind that state representatives are looking for. And when it is presented to contractors and their organizations, it creates huge resistance, especially if it is shifting risk to contractors without trading tangible opportunities for them (TRB, 1991). For example, if warranties were added to contracts without giving contractors the freedom to select materials and construction methods, contractors would consider it unfair. This could result in a list of disputes and change orders that could prevent successful deliverance of the project.

According to organizational behavior studies, change is not an easy thing to do, especially in organizations that have the setting and the culture of public agencies (Tosi, 2000). In a setting that includes too many agencies and organizations, very skillful management is required to carry out this change. Also, motivating all levels of the agency to believe in the feasibility of proposed change and provide an effective and smooth transition to the methods is essential. One way to achieve such a transition is pilot projects (Runde, 1999).

Costs affect decisions on highway contracting practices because there increasing demands on public agencies with limited resources. Unless there is a significant promised return, public agencies will remain reluctant to invest in innovation.

Chapter Three

Contractor Prequalification and Selection

3.1. Introduction

For a long time, different kinds of bonding were thought to be enough measure to guarantee contractors' compliance with all contract terms. Since surety companies focus on financial issues, using bonds only is not sufficient to reveal the technical abilities of a contractor. Thus, prequalification was added to the process to investigate a contractor's potential to succeed in carrying out the project. It was a matter of quantifying the finances and the equipment of a contractor. They are reviewed, weighted, and the sum of the positives versus the negatives is multiplied by a factor to produce the level of the aggregate work a contractor may undertake (TRB, 1991).

Whether the owner was public or private, or the project was small or large, the prequalification process varied accordingly. Private owners have more flexibility to set criteria that they think will lead to selecting a competent contractor than public owners do. Public agencies have more space to maneuver in the prequalification process than in the selection process. The state and federal legislations address the selection process in details while providing general guidelines for prequalification procedures and criteria.

The prequalification criteria has evolved and expanded to include many aspects that are believed to affect the contractor's success. Accounting, finance, organizational behavior, engineering, and other fields of science have their input into developing these criteria. People from these fields can also help apply these criteria to prospective contractors. Then, the owner decides who is prequalified and who is not. Selecting the suitable criteria requires a comprehensive and deep overview of literature and current criteria used by different owners. A detailed literature review identified forty-five widely used criteria. These formed the basis of an empirical survey, to investigate opinions of UK construction practitioners regarding prequalification criteria usage and levels of importance. Results show that the levels of importance emphasized were significantly different for some of the observed criteria, among the opinions of the public clients, private clients, clients' representatives and contractor organizations in building and civil engineering works (Wong, 2001).

These factors also affect the selection of the decision-making tools, whether they are qualitative or quantitative. The nature, consistency, and applicability of these tools should be also considered before matching any of them with the decision making.

This chapter will discuss the attributes that compose the prequalification criteria and link it to innovative contracting methods. Then it will present some prequalification decision-making models. Finally, some models used in innovative contracting and their potential to be used in prequalification will be discussed.

3.2. Objectives of Contractor Prequalification

There are three major objectives of the contractor prequalification process to ensure a maximum return on an investment with minimum completion time (Russell, 1996):

1. Assure that contractors and subcontractors are competent, responsible, and experienced, with adequate resources to complete the project. These contractors are more likely to deliver the project and optimize cost, schedule, facility performance, and safety.
2. Screen contractors whose organizations or personnel are inexperienced, or do not have an outstanding financial status.
3. Maximize competition among contractors

Of course, projects may have other objectives. Some projects aim to develop certain areas by activating the business cycle. Contractors who are capable to provide prices and executing the project by employing local communities and businesses of providing materials and labor will be preferred over those who cannot. Projects also have to comply with all government regulations. In the case of receiving federal funding, additional requirements have to be enforced to comply with federal standards regarding prequalification. Labor unions, political visions, and environmental organizations also influence prequalification, especially contractors who have bad records with any of them. Some contractors, who belong to certain ethnic minorities or are covered by Affirmative Action, may get extra credit in some prequalification areas in order to encourage people among these groups to be part of the construction industry. In the case of pilot projects that serve some studies, contractors have to fulfill the study criteria. States such as Indiana, Florida, and Massachusetts have implemented special criteria during the prequalification process of Cost-Plus-Time and Two-Step experimental projects (Runde, 1999).

3.3. Benefits and Drawbacks of Prequalification

Besides achieving the main valuable objectives of prequalification, carrying out this process is associated with benefits and drawbacks to both owners and contractors. The gains' weight on the owner's side is definitely much more than the drawbacks'. This is also valid for contractors who have outstanding performance records and sound organizations. The biggest benefit is that prequalification pays for itself and possibly even more. Owners who do not benefit from prequalification and only require surety bonding experience 15.3% average increase in cost when contractors fail (Russell, 1996).

Prequalification allows public agencies, as major buyers of construction related services, to more effectively implement continuous improvement initiatives in the construction industry. Such an improved process can result in significant reduction in bidding time. Consequently, administrative expenses will decrease since the contractor and owner's teams have already understood how to comply with the prequalification system. This kind of interaction enables the agency to identify contractors who demonstrate experience and capacity to perform projects with different levels of complexity.

Contractors can compete on a leveled ground against other prequalified contractors who have similar capacities. They will also encounter similar savings on the administrative aspect since they will not waste any resources on preparing bids in case they are disqualified. Whether they are disqualified or not, contractors have the opportunity to develop an on-going business relationship with the agency (New South Wales Department of Commerce, 2003).

Contractors may suffer from erroneous or biased denial of the bidding process, especially if there was no appeal procedure included in the process (Russell, 1996). On the other hand, developing and implementing objective criteria that will not cause such bias can be costly and requires a long time and effort to implement (Minchin, 2001). It is worthy to make such effort to produce a just process.

3.4. Contractor Prequalification Steps

There are different approaches to qualify contractors. But before choosing any of these approaches, the owner should have predetermined if the prequalification is annual or for a specific project. If it is the later, then the objectives of this specific project should be identified.

According to the owner's type and project objectives, the prequalification process generally includes the following 3 stages:

1. Setting prequalification criteria
2. Soliciting data from and about contractors
3. Prequalification decisions

Since public agencies are required to be transparent and consistent, they developed documented processes that are well defined to contractors, as well as to their own employees. The following sections will define the above three stages and present procedures currently in practice.

Prequalification Criteria

Past Performance

Cost overrun, schedule delay, and poor quality are factors for evaluating past performance (TRB, 1991). Past performance usually has high weight in the prequalification criteria. Although states differ in their criteria, many states evaluate past performance similarly. These rating systems are not only used to qualify or disqualify a contractor, but they are also used to estimate other potentials of the contractor, such as workload and bidding limits.

The Michigan Department of Transportation (MDOT) has established guidelines to evaluate a contractor's performance on work. The 1998 MDOT Construction Manual states: "Qualification of bidders maybe judged …upon the basis of proposed bidder's past performance on work of similar nature. The numerical rating factor is subject to change… as determined by the prequalification committee from a summary of reports from field engineers and further investigation by MDOT of the following factors which may permit reduction up to 100%: construction experience, quality of work… organization and personnel, equipment, … record of contract completion, record of compliance with safety specification, failure to submit required documents, … failure to execute a contract, violation of any other contract provision."

A contractor is disqualified if he receives 100% reduction because of his failure in any of the items quoted. He is rated on a scale of one (unsatisfactory) to five (excellent), in thirteen different categories. When he is rated unsatisfactory or below average, appropriate documentation should be provided. The evaluation should be for the last two construction seasons. There is a guide available for each category to ensure consistency. (MDOT Construction Manual, 1998).

The Utah DOT (UDOT) uses 76 questions covering a wide range of performance categories including project management, time scheduling, reporting and documentation, training program compliance, installed work quality, subcontractor supervision, and contract claims. Yes/No/NA questions are used and tested with different personnel to insure consistent interpretation. There is a weight of one given to each question answered positively, and the contractor's score would be received by totaling positive answers.

MDOT, UDOT, and other departments of transportation use these evaluation guides or questions to evaluate the contractor's performance during or at the end of the project. When a contractor bids for the first time on a state project, he will be asked to provide history of performed projects and references. References can be clients or his representatives. A DOT would prefer if the contractor has experience in the field that he is bidding on with other DOTs. This would facilitate data collection about the contractor from references who have mutual ground in evaluating contractors.

Financial Stability

For the successful completion of a project, the contractor needs to maintain a sufficiently sound financial position to ensure meeting the commitments under the contract. The contractor should be also assessed to make sure that he will be able to pay his debt when it falls due. This financial assessment process provides the owner assurance that the service provider can meet these expectations (APCC, 1998).

Many owners leave this task to surety companies. This way, the financial and administrative effort of buying bonds will be on the contractor's shoulders. The tradition of relying on surety companies is also very popular among public agencies. Most of the time, these agencies ask for a 100% performance bond. They also require a payment bond, which is 50% of the contract amount for small projects and can decrease as the value of the contract increases (Russell, 1996).

Current Assets, Current Liabilities, Future Assets, Future Liabilities, Earnings, Income, and Taxes are taken into consideration when evaluating the financial condition of the contractor. The contractor is required by law to have an annual financial report that provides these variables. States ask for financial statements for up to four or five fiscal years. This report must include any unsecured lines of credit extended to the contractor by banks or other financial institutions. This report is certified by a Certified Public

Accountant (CPA) who has audited the accounting transactions and records of the contractor and witnessed that they are valid (WSDOT, 2002). The financial statement includes (Stice, 1999):

1. Balance sheet
2. Income statement
3. Statement of retained earnings
4. Statement of cash flow

Relying only on a financial auditor hired by the contractor can be risky; there are records of many cases where auditors have conspired with contractors and falsified financial statements to be able to bid on projects and get awarded. The latest and most infamous example is the ENRON and Arthur Anderson scandal.

Sometimes, contractors are unwilling to provide financial data to owners because they fear that any leak of this information to competitors can jeopardize their capacity to win contracts. But they are willing to allow a third party to assess their ability to claim new projects and verify that the contractor has a valid strategy to finance these projects. The third party that is capable of doing this assessment is a Certified Financial Analyst (CFA). A CFA assessment process is similar to the process followed within lending organizations, such as banks. The owner should be the one who hires a CFA to prevent any arrangements such as those that happened in the ENRON's case (Gallegos & Associates, 1997).

Organization Type

The type of an organization provides information about its characteristics. A state that deals with a constructor will be concerned most about the flow of communications with and within this organization (Tosi, 2001). Clear-cut communication, whether it is highly formalized or open, is the heart of the contract process (Mattice, 2000). The state should configure the organizational chart of the contractor by studying any teaming arrangements. The functions and organizational structure of each team member including subconsultants, the project management structure, and any proposed guarantors should be considered. The owner should also identify whether the team will be structured as a corporation, limited liability company, general partnership, joint venture, limited partnership, or other form of organization (City Of Reno, 2001).

If a joint venture submits a bid proposal, it is typically considered to be a proposal by each of the joint venturers, jointly and separately, for the performance of the entire contract as a joint venture in accordance with the terms and conditions of the contract. Some states, like Washington, require a combined financial statement if it is a continuing joint venture. Otherwise, each member submits his own financial statement.

It is required that each part of the joint venture be prequalified by the public agency. The authorized people and their positions in the joint venture have to be declared. The experience and integrity of these people are important since they will be signing proposals, bonds, contracts, estimates, and all important documents (WSDOT, 2003).

The owners should evaluate the clarity of the responsibilities of each member of the joint venture and the level of cooperation between them. These and the above factors should be used to differentiate between applicants. Owners can decide which joint venture is easier to deal with in order to deliver the project smoothly.

Knowing the contractor organization can also indicate the potential for using partnering. Partnering requires the owner, the contractor, and the designers to sit down and align project objectives to eliminate future disputes and enhance the overall chances of project success. This cannot be suitable for certain organizational arrangements. Experience on the contractor's side of such methodology is important (Russell, 1996).

Quality Management

Past performance can be a good projection of future performance of contractors. When a contractor does not have a past performance record with an agency or he is bidding in a new field, his quality management system is an indicator of his future success. A contractor committed to the principles of quality assurance will increase the likelihood of the project being delivered to the required quality standards. The level of commitment by the contractor will be assessable from information sought about the contractor's progress towards documenting and implementing the appropriate quality system. The level of Quality Assurance sought should reflect the nature of the risk associated with a project (APCC, 1998).

One possible method to assure that only recognized quality contractors would work on projects is to specify an external quality management system certification standard. One such external certification for management systems is International Standards Organization (ISO) 9000. Another approach is the third party audit process used in Singapore called Construction Quality Assessment (CONQUAS).

ISO 9001 was reported as being used contractually on infrastructure projects in Europe (roads and metros), Africa (water supply and waste treatment), and the Far East (roads, railways and airports) as a model for project quality systems driven by owners. Documented quality systems are used, audited, and improved by project teams to reduce the cost of meeting the needs of those who finance, will use, and will be affected by the project. Owners intending to prequalify must give the construction industry time to assess and upgrade their quality systems to meet the American National Standard (ANSI/ASQC Q9001 or Q9002) (Minchin, 2001).

The ISO system requires that external audits of quality systems are performed prior to certification and that periodic reassessment is conducted to assure the certification is valid. This would effectively add a third layer of assessment to projects.

For some construction companies, adopting ISO 9000 reduces costs by using the stringent measurements and testing required in the ISO standards. The reduced rework has had the greatest benefit. Implementing ISO in some construction companies has enforced control over the concrete paving operations from batch mix production controls through placement and curing (Minchin, 2001).

CONQUAS was developed as an objective quality measurement system for vertical building construction. It has also been applied to civil construction. Its purpose is to provide an incentive scheme for encouraging contractors to improve the quality of their construction. The incentive is to award contractors by allowing them up to a 5 percent premium on bidding or $5 million, whichever is lower. Thus, a contractor with a high CONQUAS rating can bid higher than a non-rated contractor and still be awarded the contract (Minchin, 2001).

The contractor's rating depends on three components: structural, architectural, and mechanical-electrical work (M&E). This makes CONQUAS hard to be applicable to regular highway construction since there is not a lot of space for the third component. However, CONQUAS can benefit other projects, such as bridges, tunnels, and airports.

Quality assurance, quality control, and third party certification for quality management give states a wide range of systems that vary in cost and complexity. Contractors should provide proof that required systems are included and activated within their day to day activities. States should not neglect the documentation of contractors' performances even if they are certified from an accredited third party.

Technical Capability

Technical capability can be inferred from both the past performance and the quality management system that the contractor applies. But these are evaluated for different conditions that may have changed and cannot be used as a valid basis to prequalify contractors for new projects. New projects that contractors are bidding on for the first time can provide unprecedented challenges. These new challenges may require a certain kind of expertise, equipment, and design capabilities that contractors lack for specific projects. It is the state's job to verify the contractor's potential to succeed, at least technically, in his new adventure. Most states investigate the contractor's capability for new projects either through post-qualification or the submission of his Request For Proposal (RFP).

Equipment capabilities of a contractor can be evaluated by reviewing the following (WSDOT, 2003):

- A list of all the equipment that is available for the anticipated work. This list contains the quantity and a description of the equipment. The description includes size, model, capacity, ownership, years of service, present location, and dates of availability. The contractor can own, rent, or lease the equipment.
- If rental equipment is used, a letter of guarantee of availability for the contractor at the time of the project is required. This letter can either have individual listing of pieces of equipment or group them by types of equipment and their volume of special work capabilities.

The experience of the personnel in a contractor's firm should be presented for comparable projects that have similarities to the current project. They can also emphasize successful projects they handled with no prior experience. The size of those projects and reference opinions are part of the evaluation (City of Reno, 2001).

The design capability can also be assessed in a similar manner. Especially in Design-Build projects, the RFP can show the contractor's understanding of the owner's needs. It also shows his capability to transform these needs to plans, shop drawings, and specifications.

Management of Environmental Issues

A contractor can demonstrate a commitment to environmental responsibility by (APCC, 1998):

- Implementation of a corporate policy for management of environmental issues
- Development and implementation of plans to minimize the impact of construction activities
- Development of a program to train staff and employees in management of environmental issues
- Evidence of experience in environmental management on contracts, including recycling

The contractor's commitment can be assessed from the contractor's compliance with regulatory environmental laws during previous projects. Some states have their own environmental regulations and others adopt Environmental Protection Agency (EPA) manuals. Personnel on the contractor's side who have environmental certifications or have experience dealing with environmental codes are an indication of the contractor's readiness to deal with environmental issues.

Data Collection

There are four techniques to collect data (Russell, 1996):

- Credit rating services
- Site visits to contractors
- Owner past contractor performance documents
- Prequalification questionnaire

Credit rating services compile financial data on businesses, such as contractors, and sell this information to the interested parties. The National Association of Credit Managers and Dun & Bradstreet Information Services are two such agencies that provide credit ratings like "poor'" "fair," etc. It is suggested, however, that owners should verify the quality and accuracy of the data before they make prequalification decisions (Russell, 1996).

To make an assessment of the levels of efficiency and organization of the contractor's operation, a visit to an active job site and his home office should be conducted. Data collected in such visits tends to be subjective and depends on human judgment. One method to eliminate such impurities might be to have the same personnel conduct such visits (Russell, 1996). Another method is to use a Yes/No questionnaire.

When there is a history of dealing with the contractor, the owner should go back to the data collected by any of the past performance evaluation techniques. If his documentation system of the contractor's performance was sound, it could be the best way to assess the contractor.

Prequalification questionnaires are a very common way of collecting data. Almost every DOT has its own questionnaire that serves its own prequalification criteria. Some questionnaires clarify the weight of each question and the rating system that will be followed in the evaluation process (Department of Industrial Relations, 1999). Questionnaires also have an affidavit that is legally important if it is found that the contractor has falsified the data that he has provided.

Using the Internet to receive replies for questionnaires is the latest technique in data collection. Some public agencies, such as MDOT, have even extended their use of the Internet to receive bids and proposals from contractors.

Decision Making

Decision-making is very important for the prequalification process. It is particularly important for public agencies, since they need to provide justification for disqualifying any particular contractor. There are qualitative models that are easy, logical, and consistent with common sense. Quantitative models can follow the qualitative models if the owner had predetermined that he had wanted to go that far. Quantitative models require greater effort to understand and implement, which makes them undesirable (Russell, 1996).

Qualitative models can vary in their depth and complexity. Dimensional Weighing of Decision Parameters is the simplest. The owner determines each decision parameter and its relative weight of importance. Then, the aggregate rating is calculated by summing the weighted ratings of all parameters. In this method, parameters that are rated high can compensate for others that were given low ratings.

In the Dimension-Wide Strategy model, the owner selects the most salient dimension and evaluates all contractors with respect to it. Contractors are judged on that dimension only. If a contractor fails to meet the owner's expectations, then owner disqualifies him. If he passes, he is judged with the other passing contractors on the second most salient dimension, and so on.

The Two-Step Prequalification model is a combination of the previous two models. First, the Dimension-Wide Strategy is applied as preliminary screening criteria. Then, Dimensional Weighing is utilized against all parameters together. The Two-Step model allows rapid elimination of unwanted contractors, but it is possible that the first step may eliminate some contractors who have excellent records in areas the owner has not considered (Russell, 1996).

Most of the states use Dimension-Wide Strategy for annual prequalification. For example, Departments of Transportation in Massachusetts, South Dakota, and Pennsylvania use this strategy. Their prequalification questionnaires are a checklist for certain criteria. If the contractor fails to fulfill any of the DOT's standards, the contractor is disqualified. Such questionnaires include question about:

- Contractor's license
- Financial statement of the contractor including his binding capability
- Equipment inventory
- Liability and workers' compensation insurance
- Years in business and years experience as a general contractor
- Details on projects in progress
- Experience of personnel
- Failure to complete projects
- Disqualification or failure to be pre-qualified
-

At this point, most states do not enforce tough standards to prequalify contractors since prequalification is performed for all kinds of projects, regardless of size and complexity. These states just want to make sure that the contractor has certain qualifications and relevant potentials to bid on projects.

California has a large number of contractors. The California Department of Industrial relations (DIR) uses Two-Step prequalification. First, they screen contractors to shortlist them, and then they apply a uniform system to evaluate the questionnaire and the financial statement provided by the contractor. Dimensional Weighing is used to calculate the score of every contractor. This score has to be higher than or equal to a certain number. The minimum score for History of the Business and Organizational Performance is 57 out of 76 and the minimum score for Compliance with Occupational Safety and Health Laws is 38 out of 53.

3.5. Prequalification and Innovative Contracting

The general prequalification criteria established by most states do not have special direct questions regarding any of the three innovative contracting methods: Design-Build, Cost-Plus-Time, and Warranty. This is logical since the frequency of using innovative contracting is much less than traditional contracting.

It is most likely that states will use the Request For Proposal (RFP) to make sure that the contractor is competent in delivering this specific project using any of the innovative contracting methods. The RFP not only can present the profoundness of the contractor's understanding of the owner's needs, but it can be also used as another prequalification process. In a phone interview with Mr. Carpenter, the Innovative Contracting Engineer at WSDOT, he said that they use the RFP as a tool to indirectly prequalify contractors. The criteria used in the RFP addresses the same concerns raised at the annual prequalification but with more emphasis on certain areas. The emphasis and the areas of concern should vary depending on the project specific objectives and the contracting method. There may be some resistance to the use of an RFP to disqualify contractors that have passed annual prequalification (Runde, 1999). The following sections highlight these areas for the three innovative contracting methods.

Design-Build

An empirical study was conducted to determine the characteristics that the Design-Build team should have. This study concluded that teamwork and efficient coordination between different project players are the most important factors. Financial capabilities of contractors, effective implementation of project planning, technical capabilities, and past experience are also elements of critical success factors (Chan, 2001).

As an example, consider the RFP issued by the city of Reno. The RFP was issued for Reno Transportation Rail Access Corridor (ReTRAC). The RFP stated that the criteria that will be used to shortlist, in other words prequalify, contractors is as shown below in Table 1.

Table 1: Prequalification Criteria and Their Weights for ReTRAC

CRITERIA	WEIGHT
Experience and capability of proposed key staff	15%
Experience and capability of team members	20%
Project understanding, approach to Project and management plan	35%
Performance history in recent, similar projects as the Project	15%
Safety record and safety program	10%
Financial strength and qualifications	5%

At this stage, the price is not a factor in establishing the short list of finalists. The price will be a significant factor in the evaluation of the final proposals submitted by the finalists with an anticipated weighing of at least 50%.

Cost-Plus-Time

The main concern about contractors bidding on Cost-Plus-Time projects is that they may present unrealistic estimates of the numbers of days to complete the projects. By submitting proposals, the contractors present their conceptual picture of an operation sequence. They also present the assumptions upon which they will build their prices and the number of days to finish the job. Through proposals, states' engineers can determine contractors who are unaware of certain constraints and prevailing conditions that make their assumption, and consequently their bids, invalid. Some contractors may plan to take some radical measures to speed up the construction process. These measures may be inapplicable due to factors like severe impacts on neighboring areas and vitality of roads under construction in case of emergencies. The prequalification process is here to make sure that contractors understand the whole picture.

The difficulty here is that states' engineers have problems in estimating projects' durations. Studies show that in 91% of the cases, engineers' estimates are higher than contractors' estimates. This builds a strong case for contractors to argue the validity of prequalification at this stage (Herbsman, 1995).

Warranty

Contractors who seek to be prequalified for Warranty option projects should have an outstanding financial status. This is a precondition to be able to buy the required bonds, which surety companies are reluctant to sell to small or financially overloaded contractors.

Contractors should also have the experience to generate specifications upon which they will select materials. They still should have performance measurements and quality assurance procedures to evaluate the quality of the constructed elements of their projects.

The rehabilitation strategy, or preventive maintenance, should be detailed. The contractor must convince the state that he will be able to reallocate his resources in situations that require immediate remedy action. This can be challenging if the contractor is consumed with other new projects (Russell, 1999).

3.6. Selection of Contractors

Selecting the winning contractor can be a big challenge, especially if the selection process is not solely on the basis of lowest price. Low cost bidding has dominated the selection methods for a long time. Until now, the majority of public and private owners have used low bidding as the decisive criteria in selecting contractors. Contractors' capabilities to deliver a project on time, within budget, and satisfactorily complying with owner's requirements are not highly considered during the selection process. It is believed that low cost bidding is the free market approach that results in a better value for the owner's money. Owners have shifted to different selection methods since the low cost method resulted in hiring non-competent contractors. Negotiated and two-step selection practices result in less costly schedule overruns (El-Wardani, 2003).

Under innovative contracting, DOTs have gone in hard and deep on prequalification procedures. They have inserted time components into the bidding process, and they have shifted a lot of risk to the contractor's side. However, the DOTs are still using low cost as the decisive criteria for selecting contractors. Even for Design-Build projects that require very experienced and capable contractors, states still apply Low-Bid contracting after they prequalify contractors.

In addition to the Low-Bid selection method, there are two contractor selection approaches (Kumaraswamy, 1996):

- Sole or Multiple Source Negotiation
- Cost, Capabilities, and Performance Evaluation

Figure 5 describes the spectrum of selection methods from the fixed-price sealed bid to sole source selection (Molenaar, 2002).

Some private and public owners have shifted to these approaches. In order to do so, they use models and evaluation criteria because they need consistent and objective approaches (El-Wardani, 2003).

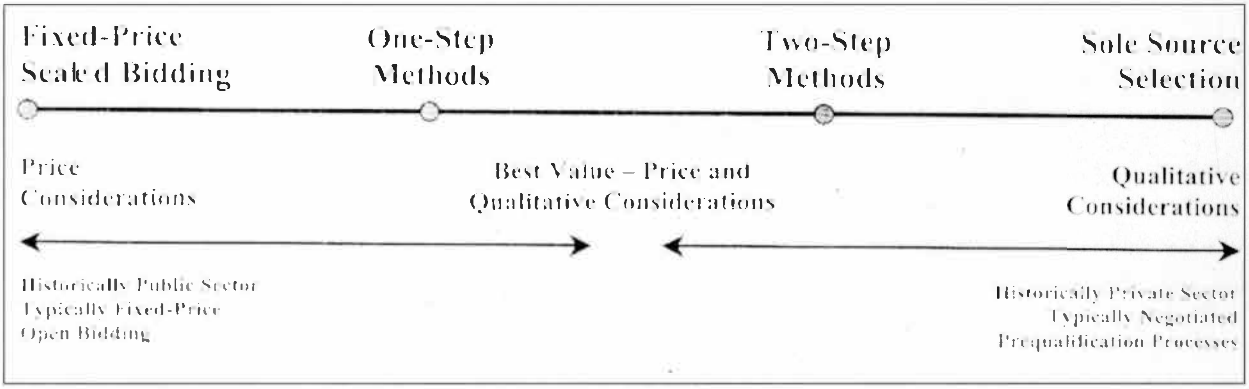

Figure 5: Spectrum of Contractor Selection Method

Evaluation criteria such as Evidential Reasoning (ER) integrate both quantitative and qualitative models to solve the contractor selection problem (Sonmez, 2001). These criteria are similar to the models presented by Russell in the contractor prequalification process.

The Multiple Criteria Decision Support System (MCDSS) is a model that consists of two steps. The first step is a screening process to shortlist contractors. The second step is selecting contractors using the Analytical Hierarchy Process (AHP). The Project Procurement System Selection Model (PPSSM) combines the AHP and value engineering into a multi-criteria selection system (Alhazmi, 2000). The model presented in this research uses low-cost bidding as the final selection method. It uses the AHP to rank contractors in order to sort them not to select the winning contractor. Value engineering is not included in the model and the prequalification criteria are different.

The AHP allows the dealing of both qualitative and quantitative criteria. After the prequalification criteria are structured into a suitable hierarchy, comparisons can be made between criteria based on either numeric or on the experience and judgment of the prequalification team members. Numeric data can be processed to match the AHP comparison scale. Qualitative judgments can be made by the prequalification team(s) with considering the rules of group decision-making. It also examines the validity of the provided data by measuring its consistency (Saaty, 1982). In addition to this, the availability of software packages makes its usage a great help to make prequalification decisions.

Chapter Four

Analytical Hierarchy Process (AHP)

4.1. Introduction

The Analytic Hierarchy Process (AHP) is a tool supported by simple mathematics that enables the explicit ranking of tangible and intangible factors against each other for the purpose of resolving conflict or setting priorities. The process has been formalized by Thomas L. Saaty and used in a wide variety of problem areas such as landfills, employee performance evaluations, and city livability rankings. The AHP enables decision-makers to represent the simultaneous interaction of many factors in complex and unstructured situations. The AHP helps identify and set priorities on the basis objectives, knowledge of, and experience with each problem (Saaty, 1982). It has become one of the essential multi-criteria decision making methods used by both management practitioners and academics. Its usage has expanded vastly across different business and management areas (Cheng, 2002).

The AHP has the following benefits that make it combine between qualitative and quantitative approaches (Saaty, 1982)).

1. It helps in dissecting the problem and structuring it into a rational decision hierarchy.
2. It gives an insight about the right data that needs to be collected about alternatives by the pair-wise comparisons conducted under each criterion or sub-criterion.

3. It prioritizes alternatives according to the pre-weighted criteria or makes a decision out of different scenarios (Cheng, 2002).
4. It examines the validity if the comparisons made between alternatives by testing these comparisons with consistency measure.

4.2. AHP Outline

The AHP is a stable process which uses basic steps that can be condensed into an outline (Saaty, 1982):

1. Define the problem and structure the hierarchy using the criteria and possible solutions
2. Construct a pair-wise comparison matrix of alternatives for each criterion or sub-criterion
3. Calculate priorities
4. Determine consistencies

Figure 6 illustrates the flow of the process. A description of each step is in the following sections (DeSilva, 2002). The flow diagram in Figure 6 presents the exact steps of the AHP that require the calculation of the Eigen vector and its maximum element λ_{max}. The process of calculating the priority vector using the exact step is laborious and based on solving a system of homogeneous linear equations. Such calculations can be done by Expert Choice, one of the AHP software packages (Expert Choice, 2000). The example presented in the next sections will calculate approximate value of the priority vector and λ_{max}, based on a simplified approximation developed by Saaty. The approximation used here is justifiable since the values calculated in both ways are identical if the comparisons are perfectly consistent. When they are nearly consistent, the values are close enough (Saaty, 1980).

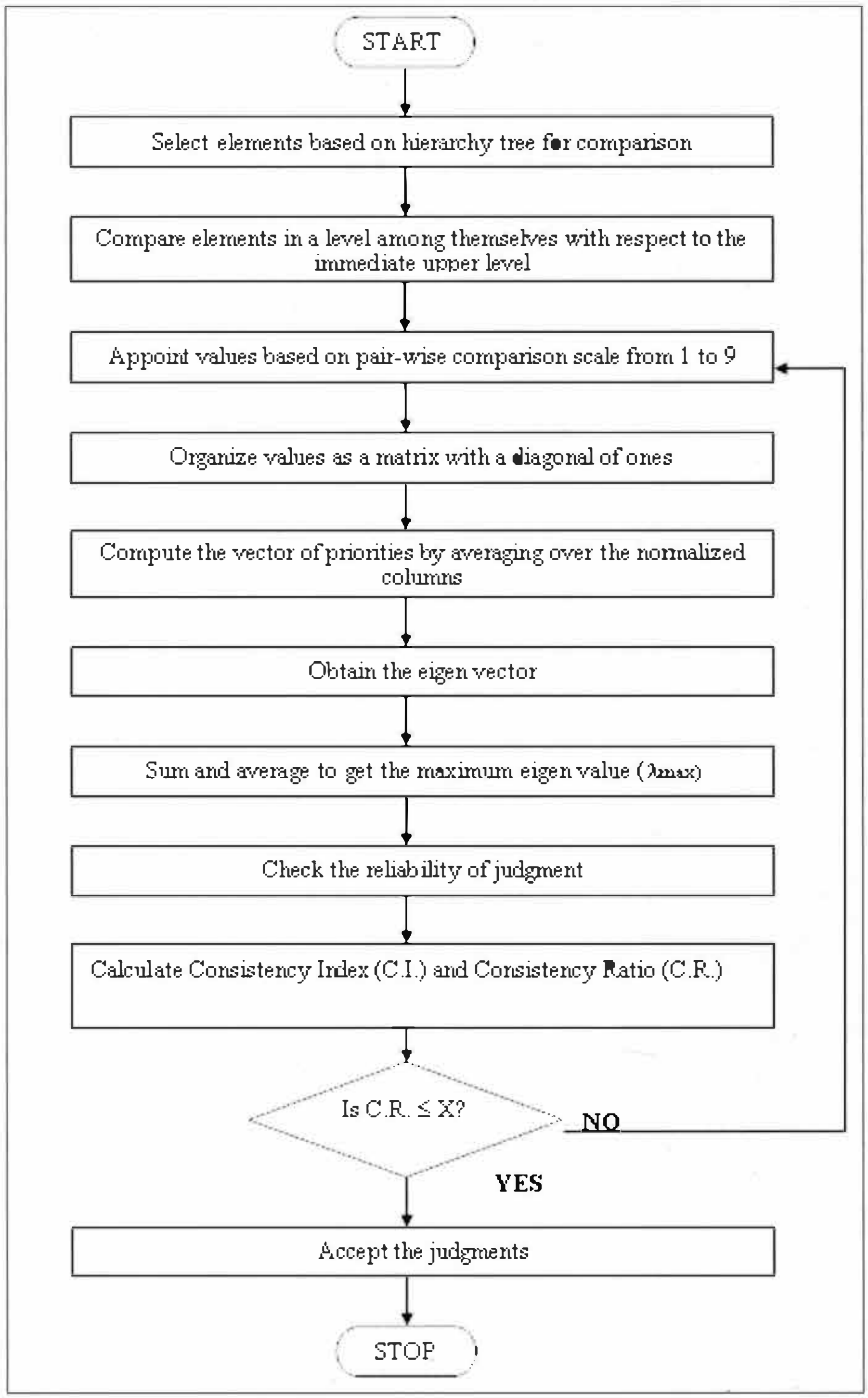

Figure 6: AHP Flow Chart (DeSilva, 2002)

Defining the Problem and Building the Hierarchies

Assessors have to make sure that they understand what the problem is. They also need to know what alternatives are available to solve the problem. Using these alternatives and the pre-determined criteria, the hierarchy can be built. The problem itself is at the highest level followed by the first decomposed level. Each criterion in this level is decomposed into sub-criteria at the next level and so on. The alternatives lay at the bottom of the hierarchy. Figure 7 shows an example of a hierarchy of four levels.

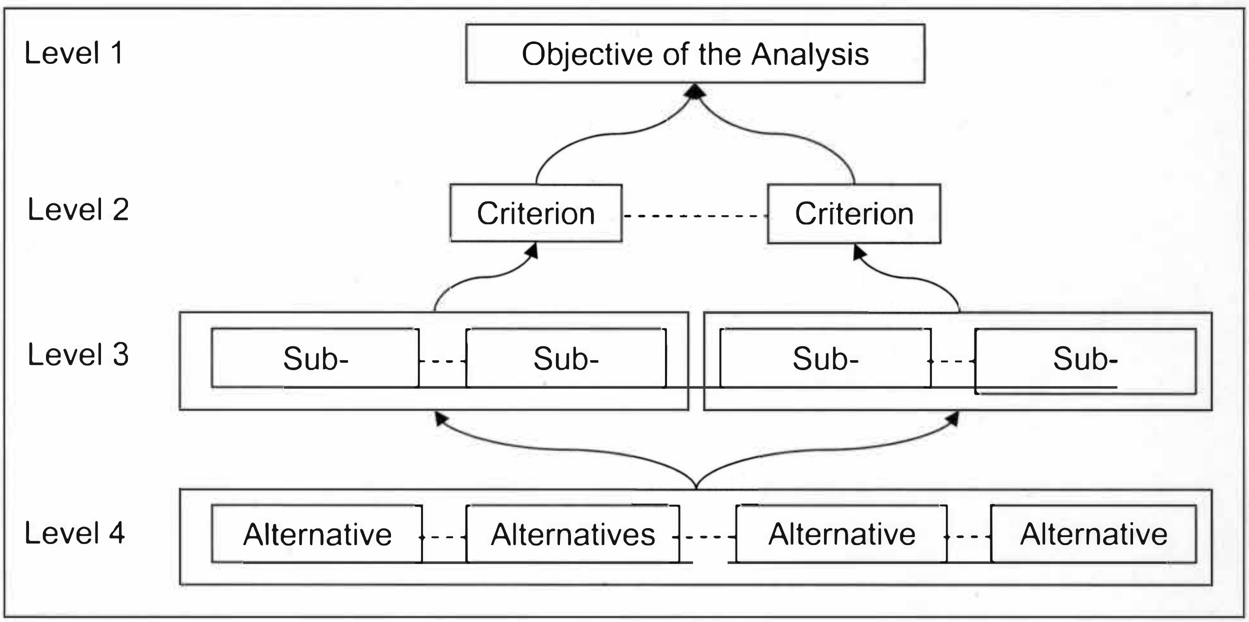

Figure 7: Hierarchy Structure for AHP

Pair-Wise Comparison

This process assigns weights of importance to each criterion or sub-criterion (Alhazmi, 2000). Systems theorists point out that complex relationships can always be analyzed by taking pairs of elements and relating them through their attributes. A matrix is the preferred form for pair-wise comparisons (Saaty, 1980). Table 2 shows an example of a pair-wise comparison between alternatives or criteria elements.

Table 2: Pair-Wise Comparison Matrix

Criteria	A	B	C
A	1	4	3
B	1/4	1	2
C	1/3	1/2	1

This table can be represented in a matrix form as follows:

$$\begin{pmatrix} 1 & 4 & 3 \\ 1/4 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{pmatrix}$$

As shown above, the diagonal of the matrix is filled with 1s. This is logical because comparing an element to itself does not result in any relative importance. When comparing element B to element A, the value ¼ is the reciprocal of the value 4 when comparing A to B.

To make sure that all the AHP users are following the same scale in establishing the relative importance, Saaty developed the scale shown in Table 3.

Table 3: Pair-Wise Comparison Scale

Importance	Definition	Explanation
1	Equal importance of both elements	Two elements contribute equally to the property
3	Weak importance of one element over another	Experience and judgment slightly favor one element over another
5	Essential or strong importance of element over another	Experience and judgment strongly favor one element over another
7	Demonstrated importance of one element over another	An element is strongly favored and its dominance is demonstrated in practice
9	Absolute importance of one element over another	The evidence is favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	Compromise is needed between two judgments

Calculating Priorities

In order to prioritize alternatives, the pair-wise comparison matrix needs to be normalized. This can be done by dividing each element of the matrix by its column total (Al-Harbi, 2001). Then each row is averaged to get the priority vector. For the above matrix, the normalized matrix is as follows:

$$\underbrace{\begin{bmatrix} .632 & .727 & .50 \\ .158 & .181 & .333 \\ .211 & .091 & .167 \end{bmatrix}}_{\text{Normalized Matrix}} \xrightarrow{\text{Average Rows}} \underbrace{\begin{bmatrix} .62 \\ .22 \\ .16 \end{bmatrix}}_{\text{Priority Vector}}$$

The value in each row represents the weight of the alternatives A, B, and C, respectively. Alternative A has the highest weight, and C has the lowest. The summation of the weights must add up to 1.

Measuring Consistencies

Consistency measure is used to screen out the inconsistency of data or judgments entered into the pair-wise comparison matrix (Cheng, 2002). The AHP measures the overall consistency of judgments by means of consistency ratio (CR).

$$CR = CI \div RI \tag{1}$$

where, CI = Consistency Index

RI = Random Index

The RI is a known value for a known order of matrix. RI for a third order matrix is 0.58

The CI is calculated using the following formula:

$$CI = (\lambda_{max} - n) \div (n-1) \tag{2}$$

where, λ_{max} = geometric mean of the matrix

n = size of the matrix

We start by multiplying the pair-wise comparison matrix by the priority vector:

$$\begin{pmatrix} 1 & 4 & 3 \\ 1/4 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{pmatrix} \quad X \quad \begin{pmatrix} .62 \\ .22 \\ .16 \end{pmatrix} \quad = \quad \begin{pmatrix} 1.98 \\ 0.69 \\ 0.48 \end{pmatrix}$$

Each element in the product of this multiplication is then divided by the corresponding element in the priority vector. The result is:

$$\begin{pmatrix} 3.19 \\ 3.14 \\ 3.00 \end{pmatrix}$$

Now we calculate λ_{max} by averaging the values in the latest matrix:

$$\lambda_{max} = (3.19 + 3.14 + 3.00) \div 3 = 3.11$$

Then, CI is calculated by substituting into equation (2):

$$CI = (3.11 - 3) \div (3 - 1) = 0.06$$

By using equation (1) and substituting RI as 0.58,

$$CR = 0.06 \div 0.58 = 0.103$$

Certain thresholds of CR have to be achieved for ascertaining consistent comparisons. The new acceptable CR values vary according to the matrix size. These new values are as follows (Saaty, 1994):

- For a third order matrix, CR is 0.05
- For a fourth order matrix, CR is 0.08
- For larger matrices, CR is 0.1

According to these thresholds, the CR of our example has exceeded 0.05. This requires reviewing the pair-wise comparisons and redoing the calculations until the CR is less than 0.05 by reviewing the judgments entered in the pair-wise comparison matrix.

Now, the criterion priorities are combined with the priorities of each decision alternative relative to each criterion in order to develop an overall priority ranking of the decision alternative, which is termed as the priority matrix (Al-Harbi, 2001).

However, the above mathematical approach is time consuming and complex to implement manually, so these operations and others can be performed using software packages. The most famous software is Expert Choice, a package developed by a company founded in 1983 by Saaty and Forman (Expert Choice, 2003).

4.3. Limitations on Using AHP and Expert Choice

The Expert Choice manual suggests limiting the number of criteria or objectives that can be used at each level to four objectives because of the comparison scale provided in Table 3. If there are more than four and there are significant relative importance discrepancies among them, it will be hard to represent such discrepancies on the nine-step scale. This is not convenient for the nature of the prequalification process. The prequalification process considers several factors at the second or third level. This scale also fails to represent contractors when there are a large number of them to prequalify, which is the common case. The developed prequalification model in this research takes this point into account by using two-step prequalification. This reduces the number of criteria and contractors to be processed in the second step.

States' or owners' prequalification teams perform the prequalification process. Using the AHP allows group members to use their experience, values, and knowledge to break down a problem into a hierarchy and solve it by the AHP steps.

Although group decision-making is encouraged to reduce subjectivity and favoritism, it does have its disadvantages. Groups have more combined knowledge and experience. Every member has useful information to share with the others. But on the other hand, group members can be socially pressured to reach quick judgments based only on one member's opinion. This is called conformity. Another disadvantage of group decision making is groupthink. In this case, group members tend to look cohesive. They also tend to make popular decisions that are not in the interest of the prequalification process, but rather receive wide acceptance among their organization and the construction community. Team members also tend to follow their leader's opinion without questioning. In this case, a leader who avoids providing any judgments is necessary. This leader can intercept any negative effect of group decision-making and redirect the team members to make the best out of their experience (Tosi, 2000).

Chapter Five

Contractor Prequalification Model

5.1. Introduction

The contractors' selection process within the public sector still has many constraints that prevent the usage of the latest selection methods that depend on negotiation or consideration of performance and capabilities as part of the selection criteria. It is difficult for the public sector to negotiate a contract or run bidding without using cost of the project as the only criteria for selecting the contractor. Public agencies have already implemented Design-Build, Cost-Plus-Time, and Warranties, but they are not able to fully benefit from these innovative methods because cost is still the decisive criterion in selecting a contractor.

There are several factors that prevent public agencies from abandoning the lowest bid selection method. Low-cost bidding's history of being fair, consistent, anti-corruption, and politically feasible makes it the most favorable. But its incapability to fulfill other objectives such as quick completion of the project and high-quality end product, leads to the development of ways to achieve these objectives without affecting the integrity of the low-bid selection method.

A model that integrates contractor prequalification with the three innovative delivery methods (Design-Build, Cost-Plus-Time, and Warranties) combined with low-bid selection method will be proposed and discussed. Using these methods and assuring that only competent contractors compete on submitting the lowest bids will produce a hybrid process that has the advantages of these delivery methods and the low-bid selection method.

This chapter presents a prequalification model that will combine efficient prequalification, innovative contracting, and the low bid selection method. It will present criteria that consider the requirements of the three innovative methods. Then, it will use the AHP as a decision-making tool to apply these criteria. Some recommendations regarding the implementation of this model will be presented last.

5.2. Prequalification Model

Any model that is to be used on a large scale and in different states has to be flexible, since each state has its own regulations and procedures. A model that can be customized to each user is needed. Figure 8 presents the flow diagram and the general structure of the developed model within the general prequalification process. The prequalification process in this model has three stages. The first stage is the annual prequalification. The second stage includes developing the prequalification criteria and gathering related data through any of the methods presented in chapter three. Each contracting method requires a different type and amount of information from the contractor. The Design-Build method requires the contractors to submit partial design of the project in their technical bids in addition to criteria-related information. In Cost-Plus-Time, the contractors do not provide a design in their technical bids, since the public agency hires a designer to develop complete designs. The contractors develop part of the design and select the material in the Warranty method. The third stage is to analyze the solicited data and apply the prequalification criteria.

All contractors who want to bid on any state job have to go through the regular annual prequalification. When there is a need to construct a project, state personnel determine the objectives and the specifications of this project. Accordingly, the suitable delivery method is selected. The delivery method and the objectives of the project determine the sequence and the criteria to be applied to prequalify interested contractors. The AHP is used here to assign weights to the criteria items.

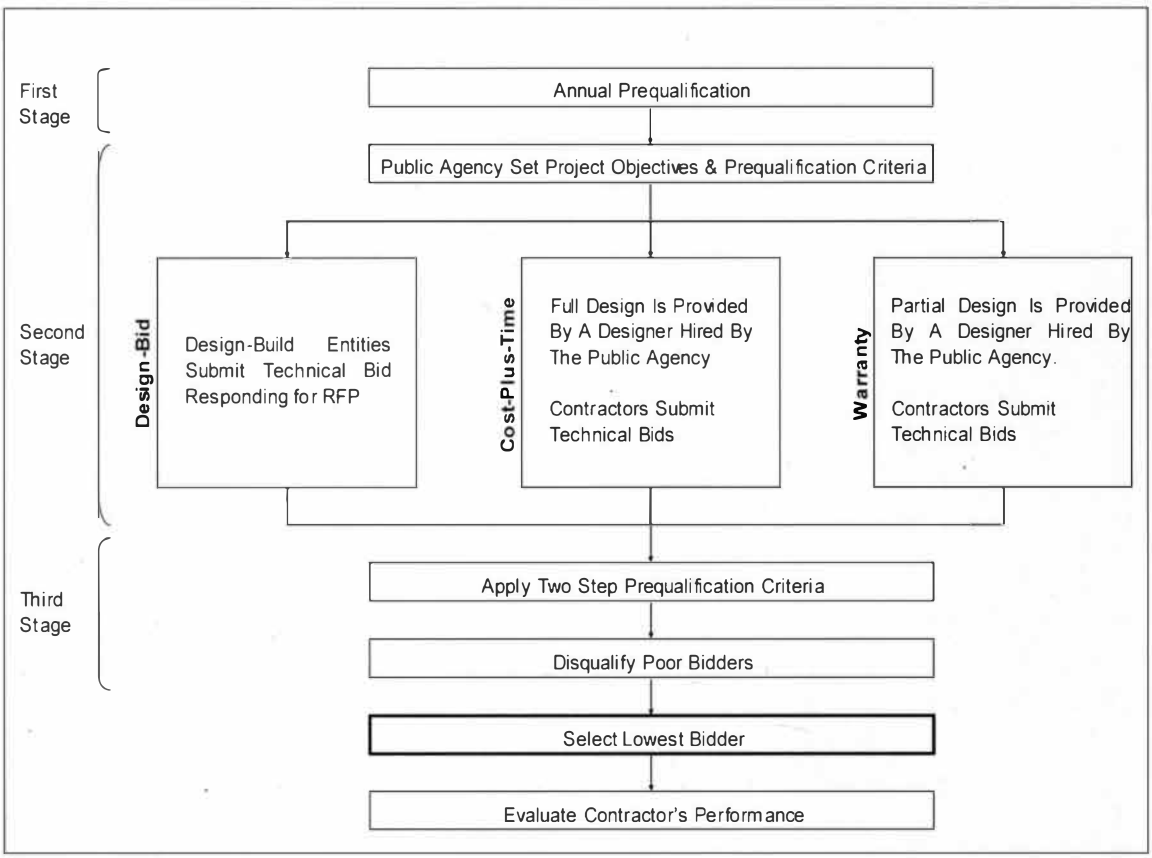

Figure 8: General Structure of the Prequalification Process

These criteria and the procedures are usually delivered to contractors through the Request For Proposal (RFP). Then, contractors submit their technical bids. The nature and the depth of details in the technical bid vary depending on the selected delivery method. The technical bid may contain updated information about the items investigated in the annual prequalification. But these bids should mainly respond to inquiries relative to the contractors' capability to deliver the project successfully using any of the three delivery systems. After assessing the technical bids of all contractors, the AHP is used again to sort contractors and determine who are eligible to participate in the final bidding process. Then, qualified contractors submit their final bids. The lowest bid is then selected. The following sections present detailed explanations of the model's components.

Annual Prequalification Criteria

The annual prequalification criteria ensure that all contractors who want to bid on public projects satisfy the minimum requirements of the public agency. The criteria also create records for the contractors in the state. The prequalification questionnaires of different public agencies in different states (Alabama, Colorado, Connecticut, Pennsylvania, Washington, Wisconsin, Oregon, California, Massachusetts, Michigan, Missouri, Mississippi, Nevada, and Florida) have been studied. Based on this research, general annual prequalification criteria were derived. These criteria take into consideration that this is a general prequalification process that focuses on minimum standards and does not consider the special demands of individual projects procured using innovative contracting methods.

The general annual prequalification criteria are met by investigating the following:

- Validity of the contractor's license or registration
- Ownership of the contractor's company and the history of the stakeholders and personnel if convicted of a crime involving the awarding of a contract
- Availability of liability and workers' compensation insurance policies
- Reviewed or audited financial statement for the current and previous fiscal years and lines of credit extended to the contractor by banks or other financial institutions
- The bonding capacity
- The maximum dollar amount of work that can be performed by the contractor's own workforce
- Prequalification and disqualification history with any state or public agency
- History of uncompleted projects or cases where surety companies have taken over a project or paid for completion because the contractor was terminated
- History of claims against the contractor's firm, claims made bye the contractor against any owner, and paid liquidated damages
- Current claims in court or arbitration
- Ineligibility to bid on public works because of breaching any of the environmental or labor codes

- Recent completed projects, references from these projects, and the classes of work performed in each project
- The classes of work the contractor is applying to be prequalified in
- The quantities, capabilities, and conditions of the contractor's owned or rented equipment

The limits that each public agency puts on each criterion vary. The nature of documents that the contractors are required to submit may also be different, but they all should have clear and representative information about the contractor's situation under that criterion.

Project Prequalification Criteria

The prequalification for each one of the innovative contracting methods coincides with the annual prequalification in several issues such as financial status, types of experience, equipment and man power. These issues may need to be investigated more extensively under innovative contracting; so they have to be considered when establishing the prequalification criteria and structure the hierarchy of the criteria. These criteria need to be added or moved up in the hierarchy to respond to the special requirements of each delivery method.

The contractors who want to deliver projects under innovative contracting need to have critical qualifications that are specifically relevant to the delivery system or to the project's objectives. Without these qualifications, it is believed that contractors will fail to achieve the project objectives even if they have other good qualifications. This, therefore, requires the use of the two-step prequalification method for two reasons. First, the public agencies have to study all the technical bids submitted by applicant contractors. These bids contain many documents and information that require tremendous effort to analyze and assess. Therefore, disqualifying contractors who do not have the critical qualifications will facilitate selection process and reduce time. The second reason is to make the decision making process less confusing. Even if we are using the AHP as a tool to make prequalification decisions, too much data and too many alternatives can make it a complex and inefficient process.

Some of the critical qualifications should be investigated only in the first step of the two- step prequalification. Others should be investigated at the first step, then considered again when comparing contractors at the second step. The criteria that should be investigated once are:

- Financial Capacity and Stability
- Bonding Capacity
- Manpower and Equipment Resources

The reason for not including these criteria in the second step is to level the ground between big contracting companies and other contractors who just meet the criteria. Public agencies should not favor big companies based solely on their huge resources. On the other hand, they should not punish smaller contractors for just meeting the criteria by comparing them to bigger contractors using the above three criteria. Still, the contractors should explain in the technical bids valid plans to finance the project in terms of expected cash flows. These financing plans are compared against each other in the second step. The following sub-sections present the two-step prequalification criteria for each innovative delivery method.

Design-Build

The purpose of using Design-Build is to deliver large projects of high complexity in short time with lower cost. This requires the contractors to have sufficient experience and good past performance in executing similar projects. It is required that their organizations have experience in delivering projects under Design-Build. If they do not, allowing them to bid on Design-Build projects may be risky, since the prices that they will submit in their final bids are not based on sound knowledge or experience of the aspects of this delivery system. Also contractors who fail to meet schedule or quality objectives must not be allowed to bid unless they can provide success stories after their failure.

If a contractor successfully performed Design-Build projects in the past for projects of different types of experience, he should be allowed to go through the second step of the project prequalification process. Through technical bids, contractors will be able to show how much they understand of the owner's needs. The experience of the two parties of the Design-Build team, the designer and the builder, should be considered. The experience of the subcontractors also counts. Their familiarity with the process flow is essential for the success of the project.

Another major reason for selecting Design Build is to deliver a high-quality end product. Past performance is the best way to anticipate the quality of production. Third party certifications can be considered an element in prequalification by the public agency if the employees of the agency are familiar with these kinds of certification and believe in them. Figure 9 illustrates the two-step prequalification criteria for the Design-Build delivery system.

The criteria in the second step contain items and factors that are believed to be the main contributors to the success of Design-Build projects. The criteria do not include minor factors since they have been already investigated in the annual prequalification. Poor status in these factors is also a valid reason for disqualification. In the public sector, it is difficult to disqualify contractors, especially if they pass the annual prequalification. It will be even more difficult to disqualify any contractor unless the decision is based on important success factors.

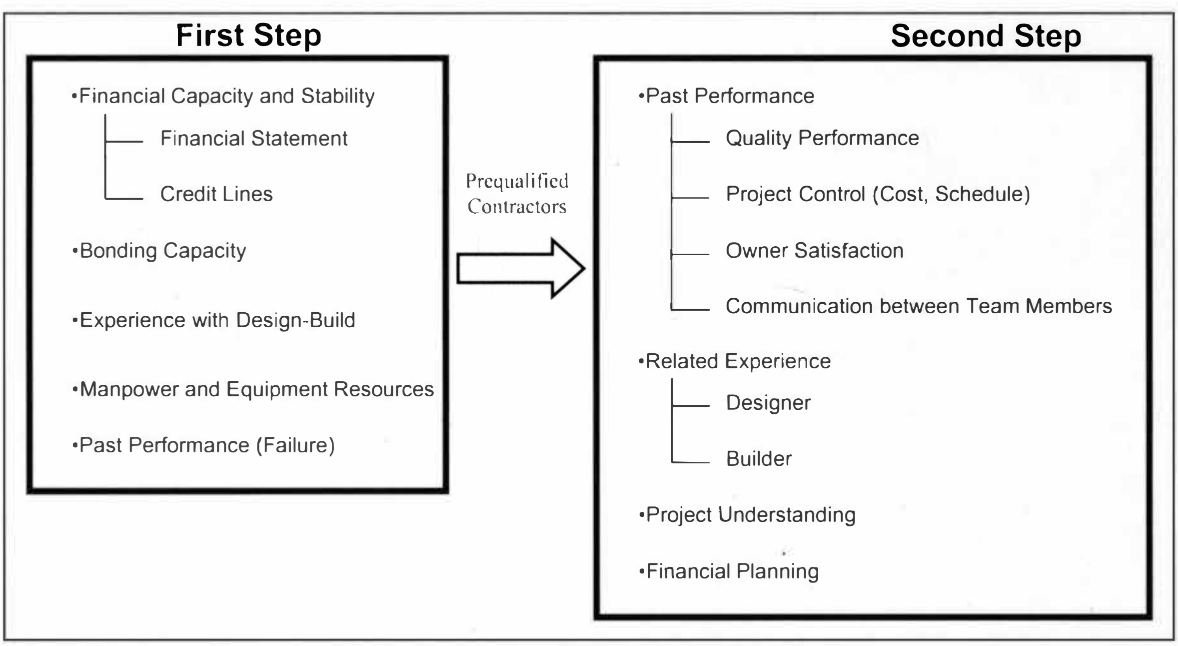

Figure 9: Design-Build Two-Step Prequalification Criteria

Cost-Plus-Time

The major goal of using Cost-Plus-Time is to deliver projects within the best time-cost combination that the contractors can offer. Contractors should have proven their capabilities to deliver projects under tight schedules. The cash flow transactions in such projects are extensive and require responsive financial management. Figure 10 illustrates the two-step prequalification criteria for such contracting method.

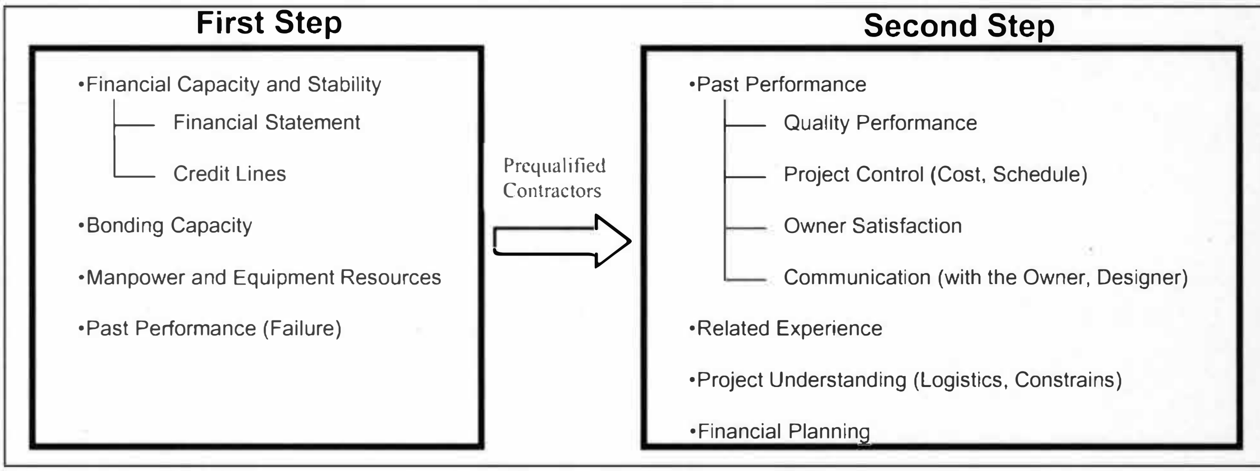

Figure 10: Cost-Plus-Time Two-Step Prequalification Criteria

Contractors should submit their technical bids based on complete and thorough analysis of the project's location. Most of the Cost-Plus-Time projects are of maintenance or reconstruction types that are performed on existing structures or highways. The contractors should be aware of the vitality of the location and the impact of all the construction operations. The nature, timing, and the length of the construction operations should be considered and provided in the technical bid, since all plans are already complete. This enables the testing of contractors' plans against the current work schedule of the public agency. This schedule should be delivered to contractors before they make their bids.

Warranty

Contractors need to have the capability of generating specifications, selecting materials and even designing some elements of the project. They also need to have sound quality control procedures since they are liable for the quality of their products for long after the project's completion. Figure 11 illustrates the prequalification criteria for the Warranty delivery method.

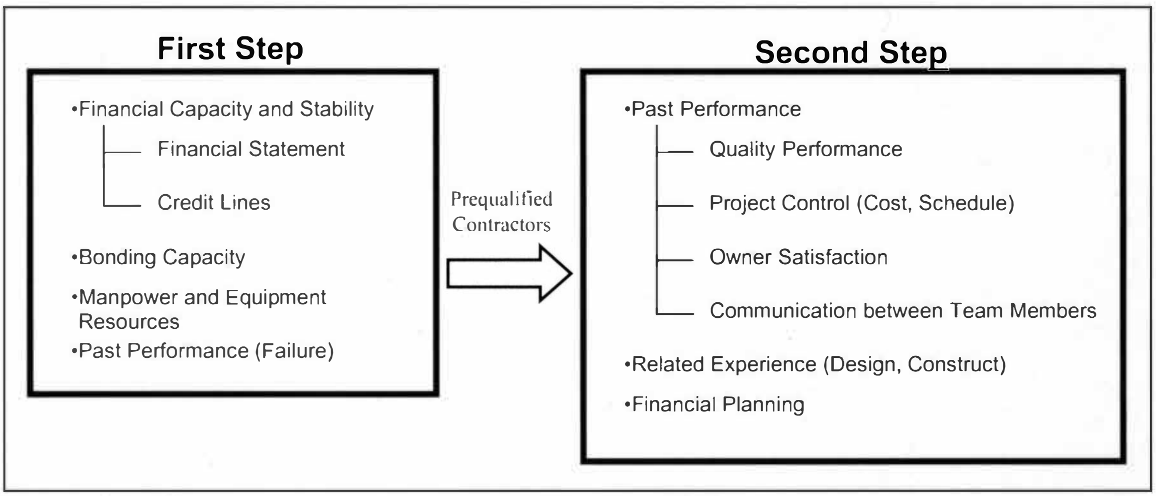

Figure 11: Warranty Two-Step Prequalification Criteria

Contractors will be responsible for maintaining the project for years after the completion date so it is essential for the success of such contracting method to have stable contractors bidding on the project. Long-term performance and maintenance bonds will be required. This is the only way to guarantee that the contractor will perform all the required maintenance services. This issue should be emphasized, since bonding companies may refuse to issue bonds to smaller contractors.

Using Warranties does not mean that the public agency can ignore other performance qualification of the contractors. Using a Warranty is an option that can be dropped if the public owner believes that the product is of good quality and will not require a significant amount of maintenance. Owners pay for high quality by the inflated prices provided in the contractor's bids.

Using AHP to Weight the Prequalification Criteria

After establishing the prequalification criteria for each delivery system, weights are assigned for each criterion and sub-criterion. The AHP is used here to facilitate this task. Public agency's experts compare between the different criteria based on their experience and judgment. Pair-wise comparison will facilitate this task.

Evaluating Technical Bids

After the contractors submit their technical bids, the state's personnel start analyzing the documents, verifying the data, and interviewing the references as a team. Their assessment of the contractors' qualifications should be made by groups and not by individuals; reducing inconsistency. It will also reduce the chance of favoring any of the contractors since it is hard for groups to agree on such unethical acts.

The prequalification team(s) focus first on data that is related to the first step's criteria. Then, they start eliminating contractors who do not satisfy it. The team(s) start analyzing data of the passing contractors that is related to the second step. This data is decomposed in a compatible way to the pre-established hierarchy of the criteria of the second step presented in figures 5.2, 5.3, 5.4. At this point, the decision makers have the processed data that they need to assess each contractor and compare him to the other contractors through pair-wise comparisons. These comparisons are performed against each previously weighted criterion.

Applying AHP to Sort Contractors

The pair-wise comparisons are processed using the AHP to rank contractors. Contractors at the bottom of the ranking are the ones who will be disqualified. If the used cut-off point is a predetermined number of contractors, contractors who are ranked behind this number will be disqualified. Another method is to disqualify a certain percentage of contractors who are at the bottom of the ranking, (e.g., 20%). The second method can be established upon statistical reasoning, which makes it more professional and acceptable. The disqualification method must be clearly articulated in the Request For Proposal.

Selecting Low-Cost Bidder

The contractors who reached this stage are eligible to provide their final bids. The final selection of contractors here is based only on cost; and the contractor with the lowest bid price is the winner. Bidding procedures followed in regular Design-Bid-Build can be used here.

The simplest representation of the prequalification models is presented in Figure 12, where it shows three major stages. First, it starts with annual prequalification for all contractors who want to bid on state's jobs. Next is the development of the two-step project specific prequalification criteria and applying it to applicant contractors. Now, qualified contractors can submit their low-cost bids in order to select the lowest bidder.

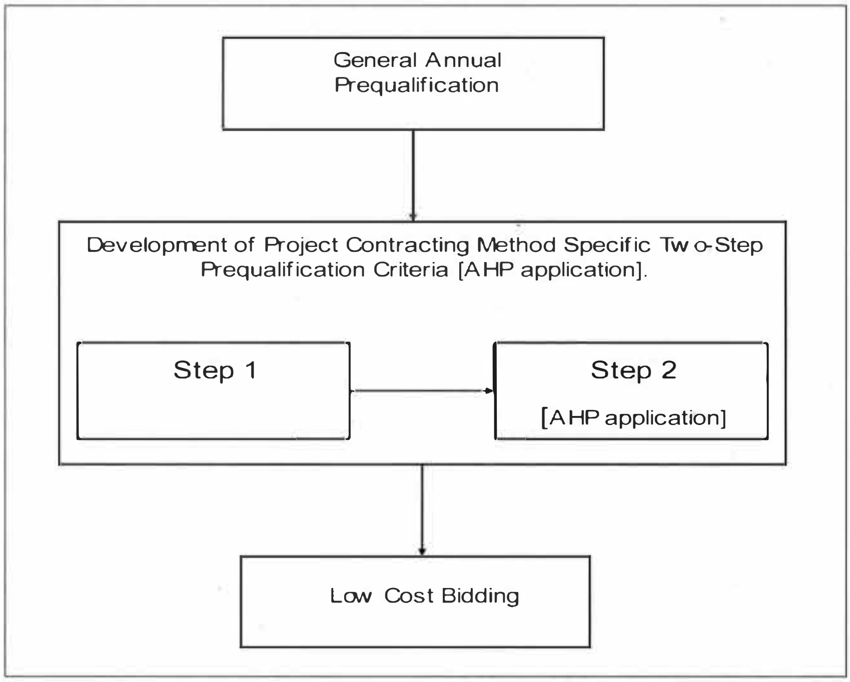

Figure 12: The Reduced Prequalification Model

5.3. Prequalification Team Decision-Making

When team members establish the prequalification criteria, they should use clear and thorough definition for each attribute or criterion. The basis for including and evaluating any of these attributes should also be well-established. Assessing the qualification of a contractor should not be rushed or based on a qualification decision made for previous projects. Also, the experience of the contractor's personnel should be considered above their personality. These decisions should be monitored by the team leader; he should have the experience to prevent the negative outcomes of group decision-making from occurring. A team leader, especially one with formal authority, should avoid providing judgments since other team members will be hesitant to argue. Still, team leaders should express their opinions.

The above should be considered whenever there is group-decision making while establishing the prequalification criteria, weighing the criteria, assessing the contractors, con ducting pair-wise comparisons, and the final qualification/disqualification decision-making.

Chapter Six

Case Studies

6.1. Introduction

Figure 13 simplifies the stages of our prequalification/bidding model. The model starts by performing the general annual prequalification for all the contractors who want to bid on public projects. Then, the two-step prequalification criteria are established and weighted for the specific innovative contracting method that will be used in that project. After receiving technical bids from contractors, the data is verified and analyzed to prequalify contractors who are eligible to reach the final low-cost bidding. The AHP is utilized twice during the prequalification process. First, it is applied to weigh the criteria before they are delivered to contractors through the RFP. Then it is used to compare between the contractors who pass the first step's criteria and rank them. The two dashed squares in Figure 13 are the steps where the AHP is used.

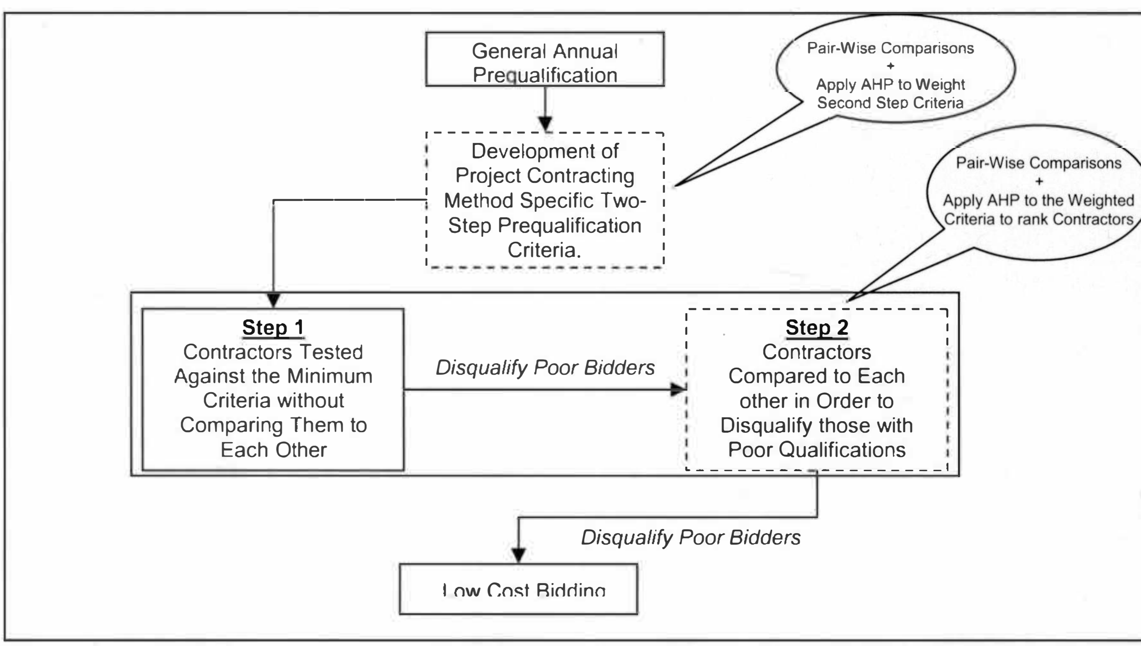

Figure 13: The Simplified Steps of the Developed Prequalification Model

This chapter investigates the application of the AHP in these two dashed steps of the suggested prequalification model for the three innovative contracting methods. The components of the model, the prequalification criteria, and sequence of the prequalification process have no similar real life examples that can be run through these models. So, an interview with Mr. Dennis Randolph was conducted to help in making pair-wise comparisons between the criteria for each innovative contracting method. Mr. Randolph is the Road Commissioner of Calhoun County and the president of the American Society of Civil Engineers (ASCE) chapter in southwest Michigan. His expertise was used to make the comparisons that were processed using the AHP to assign a weight to each criterion.

Data about contractors were used from other prequalification models and criteria and projects (Russell, 1996). This data was used to make pair-wise comparisons between contractors for each criterion. Finally the ranking of the contractors was obtained. When necessary, data was assumed to make the comparisons.

The AHP software package used to calculate the rankings of the contractors is named after the company that developed it, Expert Choice. This company is headed by Thomas L. Saaty, the formalizer of the AHP. Expert Choice facilitates the application of the AHP by enabling a quick calculation of the ranking of alternatives and measuring the consistency of our pair-wise comparisons. It also enables graphical sensitivity analyses to see how the alternatives change with respect to the importance of any criterion.

6.2. Design-Build

Problem Description

For a Design-Build project, four contractors have passed the annual and the first step prequalification criteria. Contractors A, B, C, and D are now to be compared under the second step criteria (Figure 9) to be ranked and qualified to bid in the final low-bid selection step. The data related to the second step criteria were collected and put in the hands of the prequalification team members to start comparing between applicants. They used their expertise and judgment to establish the pair-wise comparisons that are provided in tables 4 through 11. The hierarchy structure is shown in Figure 14. This figure shows the corresponding tables for pair-wise comparisons.

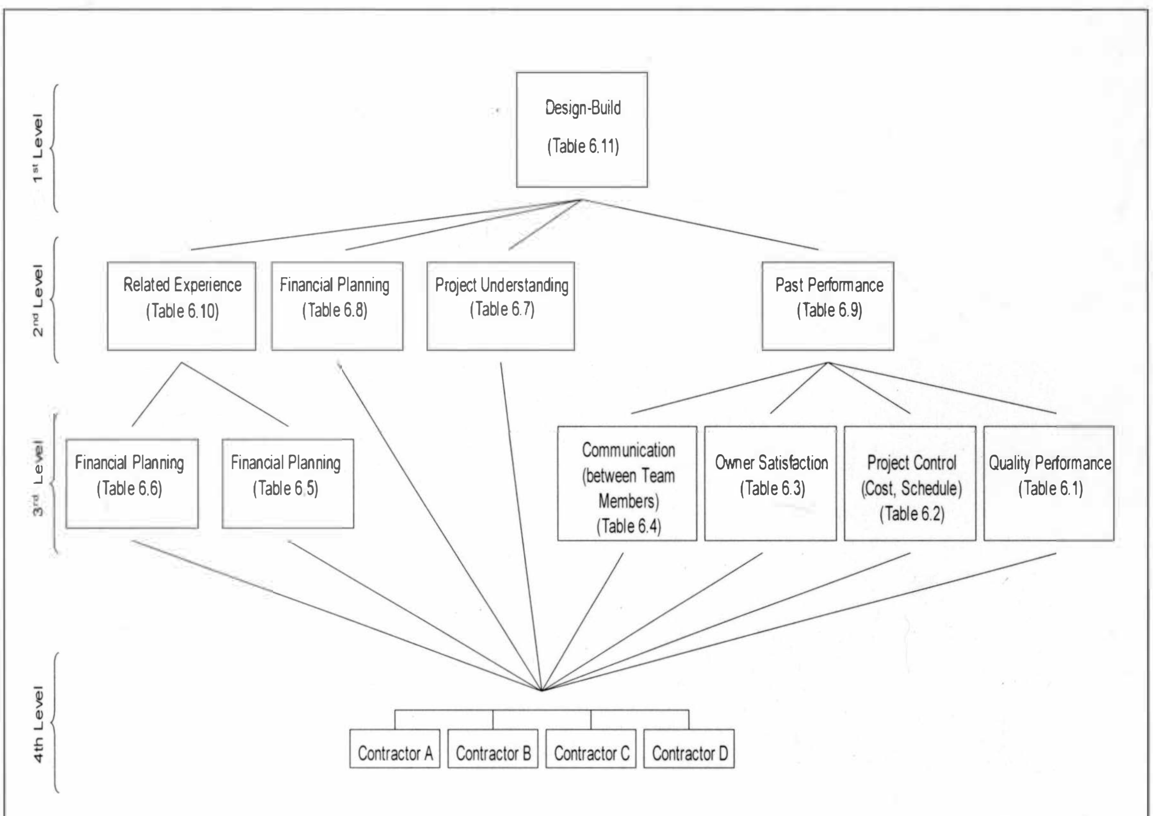

Figure 14: Design-Build Hierarchy and Corresponding Pair-Wise Comparison Tables' Numbers

Figure 15 shows the Expert Choice's interface after entering the criteria and before making any of the pair-wise comparisons. The alternatives are also entered and no priorities are calculated or shown next to each alternative. The bullets are still circular as an indication that there are missing pair-wise comparisons that need to be made.

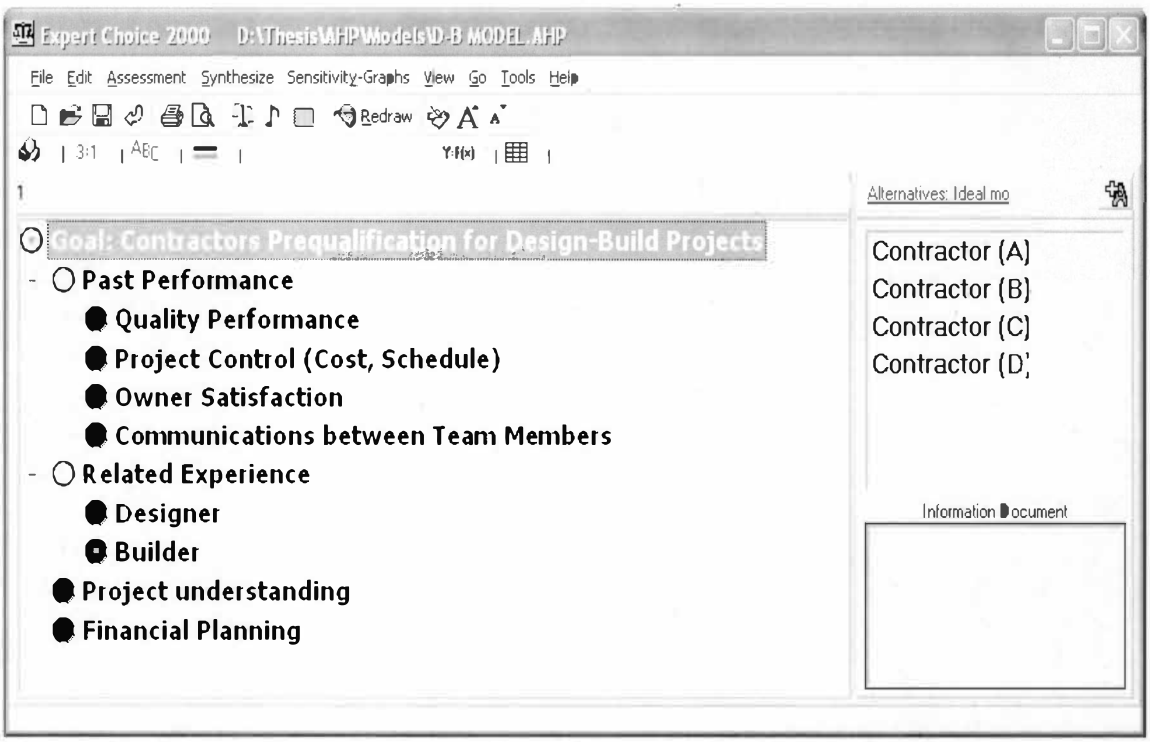

Figure 15: Expert Choice's Criteria Input Interface for Design-Build

Table 4: Quality Performance Pair-Wise Comparison

Quality Performance	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	5	4	1
Contractor (B)	1/5	1	1	1/4
Contractor (C)	4	1	1	1/3
Contractor (D)	1	4	3	1
	Inconsistency = 0.01			

In Table 4, contractor A is believed to have better qualifications than B and C since he received a 5 and 4, respectively, when he was compared to them. Contractors A and B have equal qualifications since the record in comparison table is 1 when they are compared against each other. This also applies to contractors B and C. The inconsistency ratio is lower than 0.08, which is the max threshold for a fourth order matrix. The same discussion can be made for the remaining comparisons.

Table 4 represents the data that was fed into the Expert Choice pair-wise comparison window that is shown in Figure 16. The inconsistency appears in the bottom left corner of the table. The ranking scale can be moved to the right or the left to compare between alternatives.

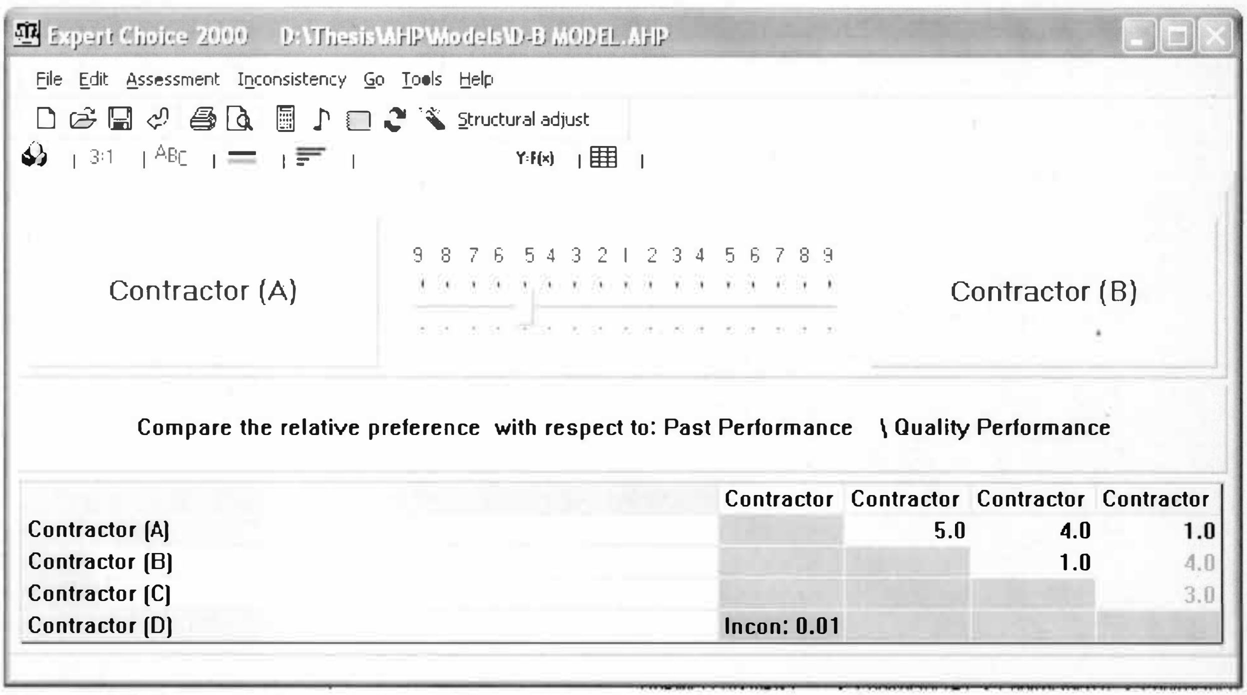

Figure 16: Expert Choice's Pair-Wise Comparison Input Interface

Table 5: Project Control (Cost, Schedule) Pair-Wise Comparison

Project Control (Cost, Schedule)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	5	4	4
Contractor (B)	5	1	1	1
Contractor (C)	1/4	1	1	1
Contractor (D)	1	1	1	1
	Inconsistency = 0.00			

Table 6: Owner Satisfaction Pair-Wise Comparison

Owner Satisfaction	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	5	2	2
Contractor (B)	1/5	1	1/3	1/3
Contractor (C)	1/2	3	1	1
Contractor (D)	1/2	3	1	1
	Inconsistency = 0.01			

Table 7: Communication Between Team Members Pair-Wise Comparison

Communication between Team Members	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	3	3	1
Contractor (B)	1/3	1	1	1/2
Contractor (C)	1/3	1	1	1
Contractor (D)	1	2	1	1
	Inconsistency = 0.01			

Table 8: Designer Experience Pair-Wise Comparison

Designer Experience	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/4	1	1/2
Contractor (B)	4	1	4	2
Contractor (C)	1	1/4	1	1/2
Contractor (D)	2	1/2	2	1
	Inconsistency = 0.00			

Table 9: Builder Experience Pair-Wise Comparison

Quality Performance	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/3	1/3	1/4
Contractor (B)	3	1	2	1/2
Contractor (C)	3	1/2	1	1/3
Contractor (D)	4	2	1	1
	Inconsistency = 0.03			

Table 10: Project Understanding Pair-Wise Comparison

Project Understanding	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/4	2	1
Contractor (B)	4	1	5	4
Contractor (C)	1/2	1/5	1	1
Contractor (D)	1	1/4	1	1
	Inconsistency = 0.02			

Table 11: Financial Planning Pair-Wise Comparison

Financial Planning	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1	1	1
Contractor (B)	1	1	1	1
Contractor (C)	1	1	1	1
Contractor (D)	1	1	1	1
	Inconsistency = 0.00			

Criteria Weight Development

In order to weigh each criterion, we used the pair-wise comparisons between criteria made by Mr. Randolph. He used his experience to compare between the criteria and feed the comparisons to Expert Choice. He monitored the consistency ratio at the end of each comparison and made sure that it did not exceed the maximum threshold value corresponding to the size of the pair-wise comparison matrix. These comparisons are provided in tables 12, 13, and 14.

Table 12: Design-Build Pair-Wise Comparison

Design-Build	Past Performance	Related Experience	Project Understanding	Financial Planning
Past Performance	1	2	1/3	1/2
Related Experience	1/2	1	1/2	1/2
Project Understanding	3	2	1	2
Financial Planning	2	2	½	1
	Inconsistency = 0.05			

Table 12 indicates that Mr. Randolph considers project understanding more important than the other criteria; he used low scale ranks (3 and 2) rather than higher ones. This means that he believes that project understanding is more important than the other criteria, but the other criteria still need to be seriously considered. The table also indicates that having related experience to the type of the coming project is slightly more important than the contractor's performance in other types of previous projects. Mr. Randolph believes in giving contractors another chance unless they have truly failed on a project. If they do have a history of serious failures, they should not have passed the first step of prequalification provided in Figure 5.2.

Table 13: Past Performance Pair-Wise Comparison

Past Performance	Quality Performance	Project Control (Cost, Schedule)	Owner Satisfaction	Communication Between Team Members
Quality Performance	1	3	1	1/2
Project Control (Cost, Schedule)	1/3	1	1/3	1/7
Owner Satisfaction	1	3	1	1/2
Communication Between Team Members	2	7	2	1
	Inconsistency = 0.00			

Table 13 indicates that communication between contractor's team members is much more important than his past performance in controlling cost and schedule, but it is slightly more important than his past quality performance and previous owners' satisfaction.

Table 14: Related Experience Pair-Wise Comparison

Related Experience	Designer	Builder
Designer	1	1/2
Builder	2	1
	Inconsistency = 0.00	

The designer's related experience is more important in Mr. Randolph's opinion than the builder's as shown in Table 14.

Ranking Contractors

After all the pair-wise comparisons are complete, Expert Choice calculates the local priorities for each comparison table, and then combines them up the hierarchy to calculate the overall ranking of the contractors. Local priorities and the overall ranking of the contractors are assigned to each criterion in the hierarchy as shown Figure 17.

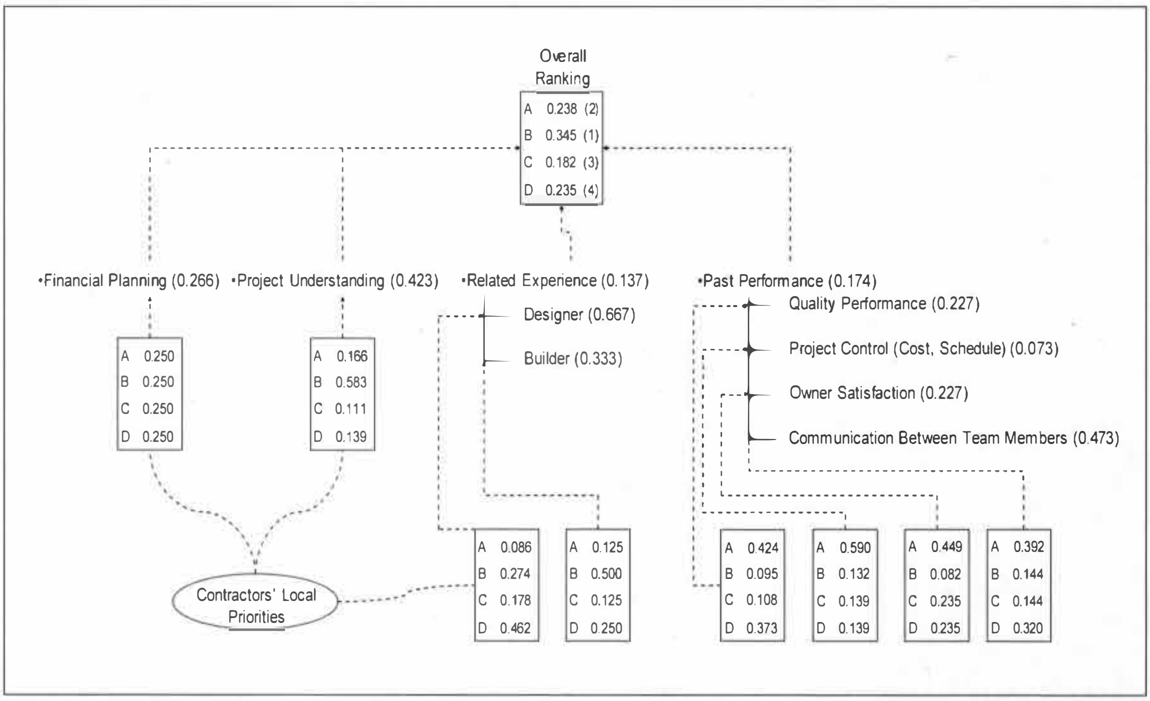

Figure 17: The Hierarchy, Local Priorities, and the Overall Ranking of Contractors (Design - Build)

Figure 18 shows the output for Design-Build provided by Expert Choice. The overall ranking of the contractors is provided under the alternative box. The overall goal of the process is the Contractors Prequalification for Design-Build Project. Each criterion has its importance level written next to it.

Contractor B tops the ranking. Then comes A, then D, and finally, C. Contractor B has the highest local priority under the criteria with highest weight such as project understanding. Contractor A has the highest ranking under all past performance sub-criteria, but past performance weighs almost only 40% of project understanding. This is what advantaged contractor B over contractor A.

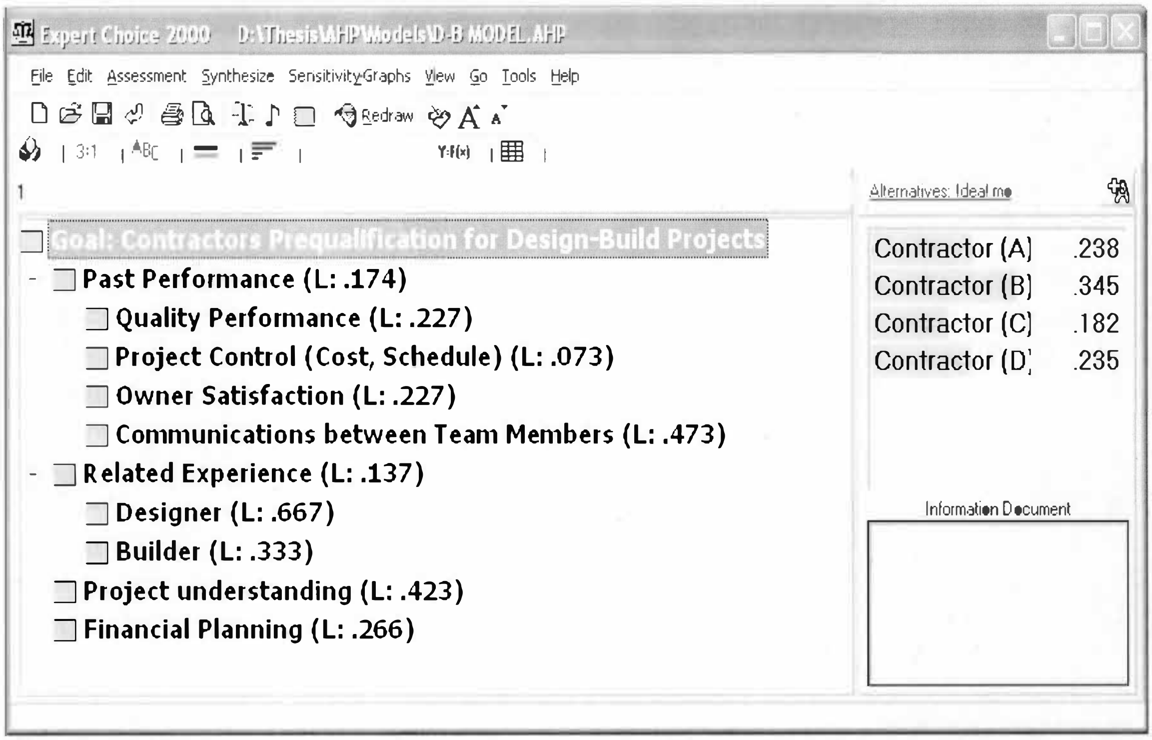

Figure 18: Expert Choice's Output Interface for Design-Build

6.3. Cost-Plus-Time

Problem Description

Four annually prequalified contractors, A, B, C, and D, intend to bid on a Cost-Plus-Time project. They submitted their technical bids and passed the first step prequalification criteria (Figure 10). The prequalification experts at the public agency analyze the contractors' technical bids to compare them to the second step criteria illustrated in the same figure. Based on their expertise, they use the collected data to produce the pair-wise comparison shown in tables 15 through 21. The hierarchy structure is shown in Figure 19. This figure shows the corresponding tables for pair-wise comparisons.

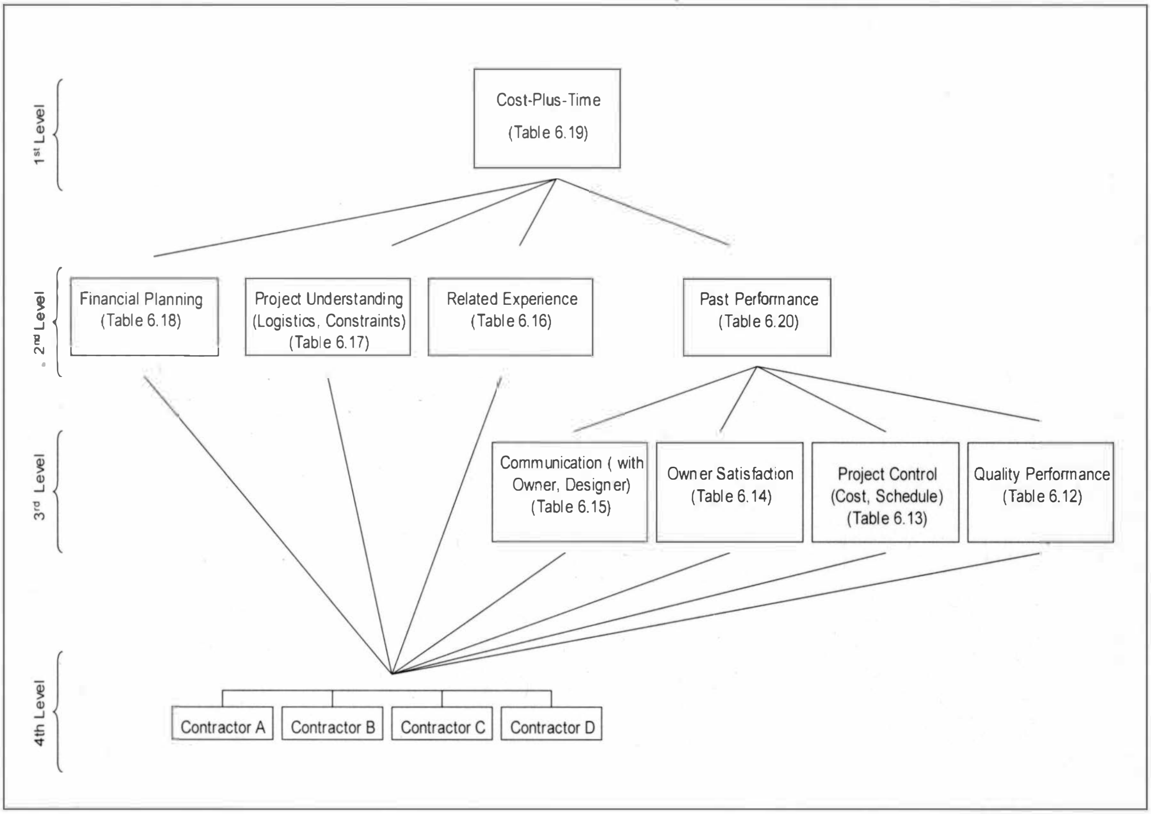

Figure 19: Cost-Plus-Time Hierarchy and Corresponding Pair-Wise Comparison Tables' Numbers

Table 15: Quality Performance Pair-Wise Comparison

Quality Performance	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/2	1/4	2
Contractor (B)	2	1	1/2	4
Contractor (C)	4	2	1	6
Contractor (D)	1/2	1/4	1/6	1
	Inconsistency = 0.01			

Table 16: Project Control (Cost, Schedule) Pair-Wise Comparison

Project Control (Cost, Schedule)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	2	4	4
Contractor (B)	1/2	1	2	2
Contractor (C)	1/4	1	1	1
Contractor (D)	1/4	1/2	1	1
	Inconsistency = 0.00			

Table 17: Owner Satisfaction Pair-Wise Comparison

Owner Satisfaction	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1	1	1
Contractor (B)	1	1	1	1
Contractor (C)	1	1	1	1
Contractor (D)	1	1	1	1
	Inconsistency = 0.00			

Table 18: Communication (with the Owner, Designer) Pair-Wise Comparison

Communication (with the Owner, Designer)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1	1/2	2
Contractor (B)	1	1	1/2	3
Contractor (C)	2	2	1	3
Contractor (D)	1/2	1/3	1/3	1
	Inconsistency = 0.01			

Table 19: Related Experience Pair-Wise Comparison

Related Experience	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	3	2	4
Contractor (B)	1/3	1	1/2	2
Contractor (C)	1/2	2	1	3
Contractor (D)	1/4	1/2	1/3	1
	Inconsistency = 0.01			

Table 20: Project Understanding (Logistics, Constraints) Pair-Wise Comparison

Project Understanding (Logistics, Constraints)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/2	2	1
Contractor (B)	2	1	4	2
Contractor (C)	1/2	1/5	1	1
Contractor (D)	1	1/4	1	1
	Inconsistency = 0.02			

Table 21: Financial Planning Pair-Wise Comparison

Financial Planning	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1	1	1
Contractor (B)	1	1	1	1
Contractor (C)	1	1	1	1
Contractor (D)	1	1	1	1
	Inconsistency = 0.00			

Criteria Weight Development

The same method that was used in Design-Build is used here to weigh the criteria. The hierarchy of the criteria, shown in Figure 10, requires only two pair-wise comparisons that are provided in Table 22 and Table 23.

Project understanding for this innovative contracting method is also preferred over the other criteria as shown in Table 22. The inconsistency ratio in this table is 0.06. It is below the maximum allowable value for a fourth order matrix, but it is higher than previous comparisons. The reason for relatively high value is the comparison between past performance and project understanding. If we change the comparison value from 1/3 to 1/4, the inconsistency ratio will drop to 0.03. This can be explained by looking at the comparison value between project understanding and financial planning. The comparison value, 3, indicates that project understanding is more important than financial planning. However, both of them have the same value, 1/3, when past performance is compared to them, which indicates similar importance. This is inconsistent with the previously mentioned 3 value.

Table 22: Cost-Plus-Time Pair-Wise Comparison

Cost-Plus-Time	Past Performance	Related Experience	Project Understanding	Financial Planning
Past Performance	1	1/2	1/3	1/3
Related Experience	1/2	1	1/4	1/2
Project Understanding	3	4	1	3
Financial Planning	3	2	1/3	1
	Inconsistency = 0.06			

Table 23: Past Performance Pair-Wise Comparison

Past Performance	Quality Performance	Project Control (Cost, Schedule)	Owner Satisfaction	Communication Between Team Members
Quality Performance	1	3	1	2
Project Control (Cost, Schedule)	1/3	1	1/2	1/2
Owner Satisfaction	1	2	1	2
Communication (with Owner, Designer)	1/2	2	1/2	1
	Inconsistency = 0.02			

Ranking Contractors

The software is then used to calculate all the local priorities, criteria weights, and the overall ranking of the contractors. The final results are shown in Figure 20.

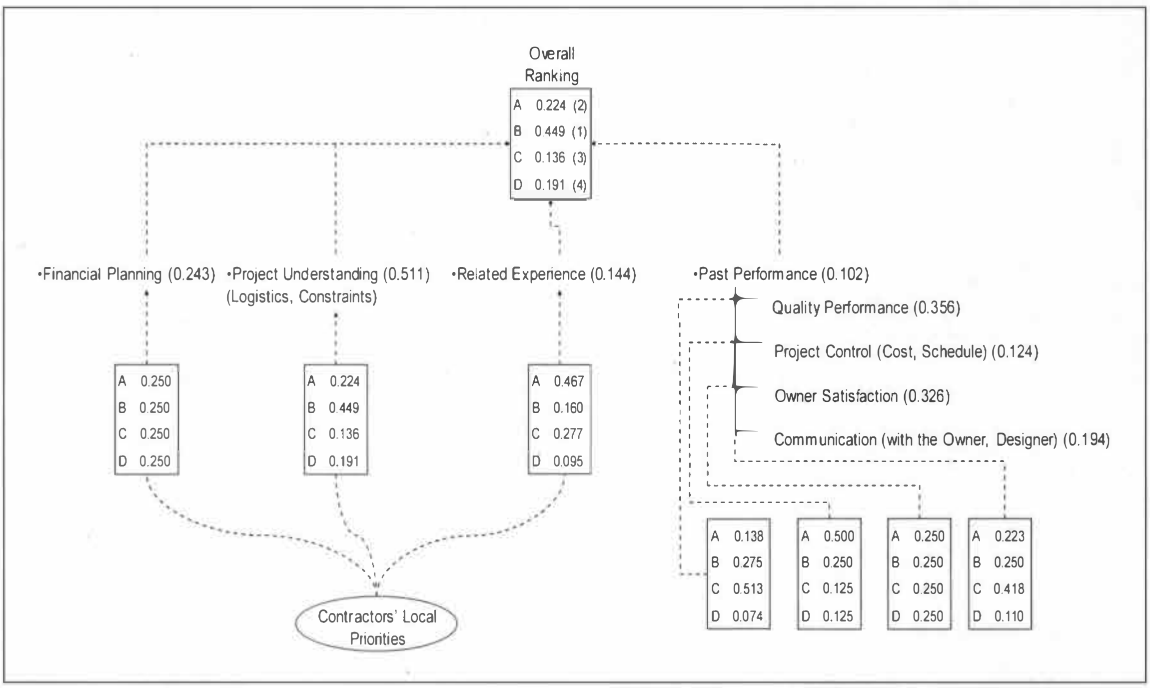

Figure 20: The Hierarchy, Local Priorities, and the Overall Ranking of Contractors (Cost-Plus-Time)

Contractor B has the highest ranking. He earned a high local priority in project understanding (0.449). Past performance is a criterion with high weight (0.551). Winning this criterion with high local priority enabled contractor B to top the ranking since he has outstanding local priorities in other criteria.

Figure 21 shows that overall ranking of the contractors and the relative importance weights for the criteria as provided by Expert Choice.

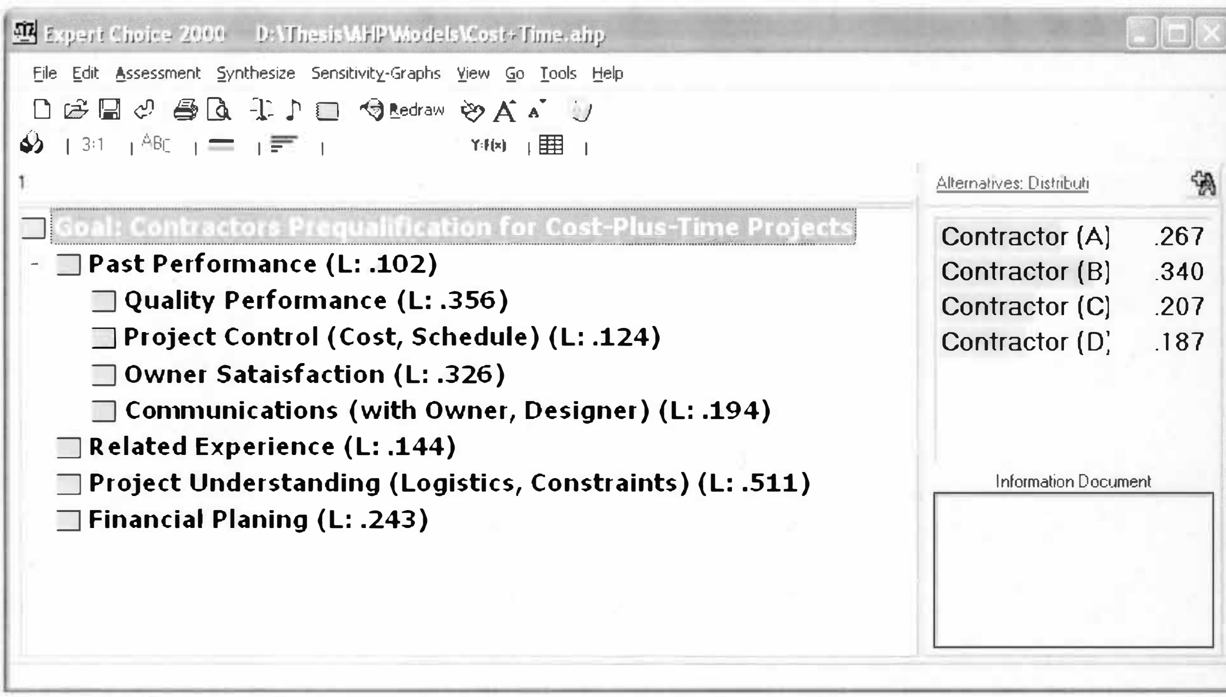

Figure 21: Expert Choice's Output Interface for Cost-Plus-Time

6.4. Warranty

Problem Description

Contractors A, B, C, and D want to bid on a Warranty public project. They passed through the first step prequalification and are waiting to be ranked according to the second step criteria shown in Figure 11. The data collected from and about the contractors is assessed and the prequalification experts made their judgments about the contractors' relative performance. The pair-wise comparisons are provided in tables 24 through 29. These tables are pair wise comparisons for the hierarchy shown in Figure 22.

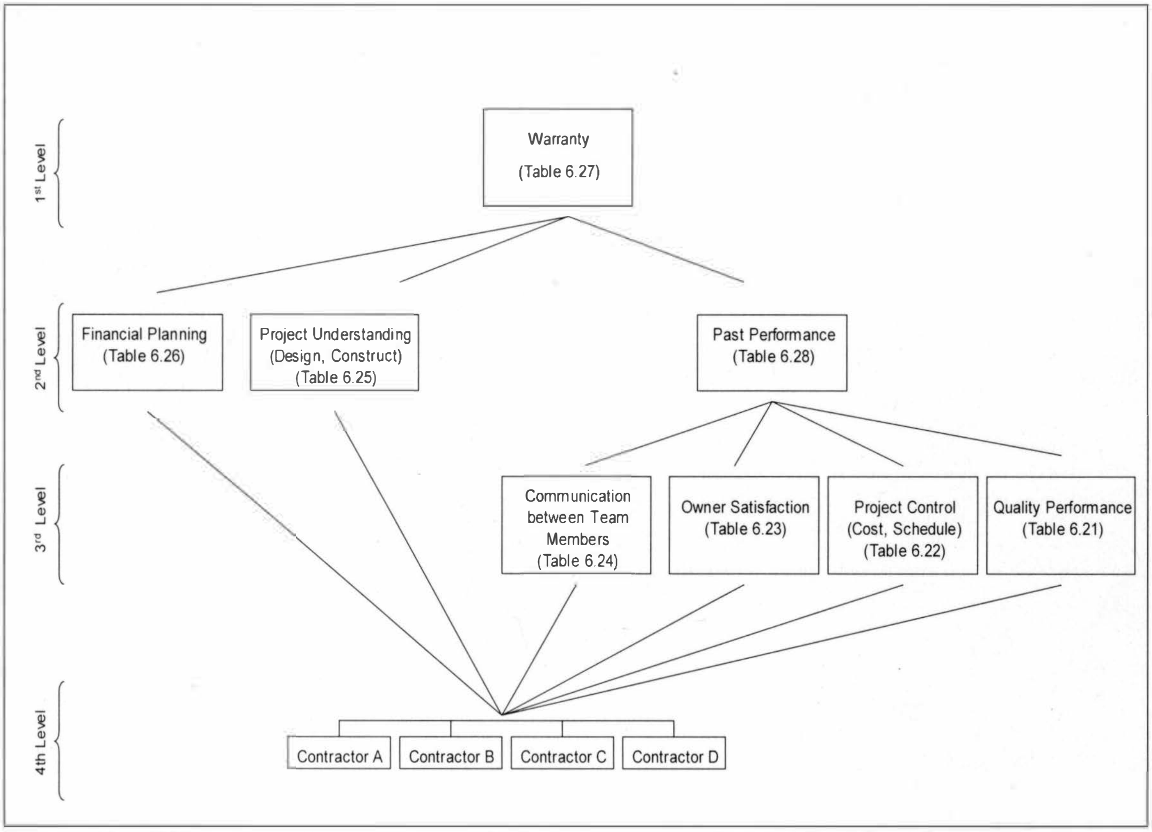

Figure 22: Warranty Hierarchy and Corresponding Pair-Wise Comparison Tables' Numbers

Table 24: Quality Performance Pair-Wise Comparison

Quality Performance	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	3	2	1/4
Contractor (B)	1/3	1	1/2	1/7
Contractor (C)	1/2	2	1	1/7
Contractor (D)	4	7	7	1
	Inconsistency = 0.02			

Table 25: Project Control (Cost, Schedule) Pair-Wise Comparison

Project Control (Cost, Schedule)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	3	3	4
Contractor (B)	1/3	1	1	2
Contractor (C)	1/3	1	1	2
Contractor (D)	1/4	1/2	1/2	1
	Inconsistency = 0.01			

Table 26: Owner Satisfaction Pair-Wise Comparison

Owner Satisfaction	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	3	3	1
Contractor (B)	1/3	1	2	1/3
Contractor (C)	1/3	1	1	1/3
Contractor (D)	1	3	3	1
	Inconsistency = 0.02			

Table 27: Communication between Team members Pair-Wise Comparison

Communication (with the Owner, Designer)	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	4	2	1
Contractor (B)	1	1	1/2	1/3
Contractor (C)	2	2	1	1/2
Contractor (D)	1/2	1/3	1/3	1
	Inconsistency = 0.00			

Table 28: Related Experience (Design, Construct) Pair-Wise Comparison

Related Experience	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	1/3	1	1/3
Contractor (B)	3	1	3	3
Contractor (C)	1	1/3	1	1/2
Contractor (D)	3	1/3	2	1
	Inconsistency = 0.04			

Table 29: Financial Planning Pair-Wise Comparison

Financial Planning	Contractor (A)	Contractor (B)	Contractor (C)	Contractor (D)
Contractor (A)	1	2	2	1/4
Contractor (B)	1/2	1	1	1/5
Contractor (C)	½	1	1	1/4
Contractor (D)	5	5	4	1
	Inconsistency = 0.02			

Criteria Weight Development

The hierarchy of the second step criteria requires only two pair wise comparisons as provided in tables 30 and 31.

Table 30: Warranty Pair-Wise Comparison

Cost-Plus-Time	Past Performance	Related Experience (Design, Construct)	Financial Planning
Past Performance	1	1/2	1/2
Related Experience	2	1	2
Financial Planning	2	1/2	1
	Inconsistency = 0.05		

The inconsistency ratio in Table 30 is within the allowable limit but a little bit high. When related experience and financial planning are compared to past performance, they both receive 2, but when they are compared to each other, they also receive 2. This means that they are more important than past performance in the same degree, and at the same time, one of them is more important than the other. This is inconsistent.

Table 31: Past Performance Pair-Wise Comparison

Past Performance	Quality Performance	Project Control (Cost, Schedule)	Owner Satisfaction	Communication Between Team Members
Quality Performance	1	3	1/3	1/2
Project Control (Cost, Schedule)	1/3	1	1/3	1/2
Owner Satisfaction	3	1/3	1	2
Communication between team Members	2	2	1/2	1
	Inconsistency = 0.06			

Ranking Contractors

This data is fed to Expert Choice to perform the AHP calculations and provide the local priorities and the overall ranking of the contractors. Figure 23 illustrates the criteria's hierarchy, local priorities, and the overall ranking of the contractors.

Contractor D has the highest ranking. He was not ranked the first under the highest weight criteria, which is related experience, but he received good local priority (0.255) compared to contractor B who is the highest (0.490). Contractor B received very low local priorities for all the sub-criteria of past performance, while contractor D scored high. This is what made contractor D get higher ranking than contractor B.

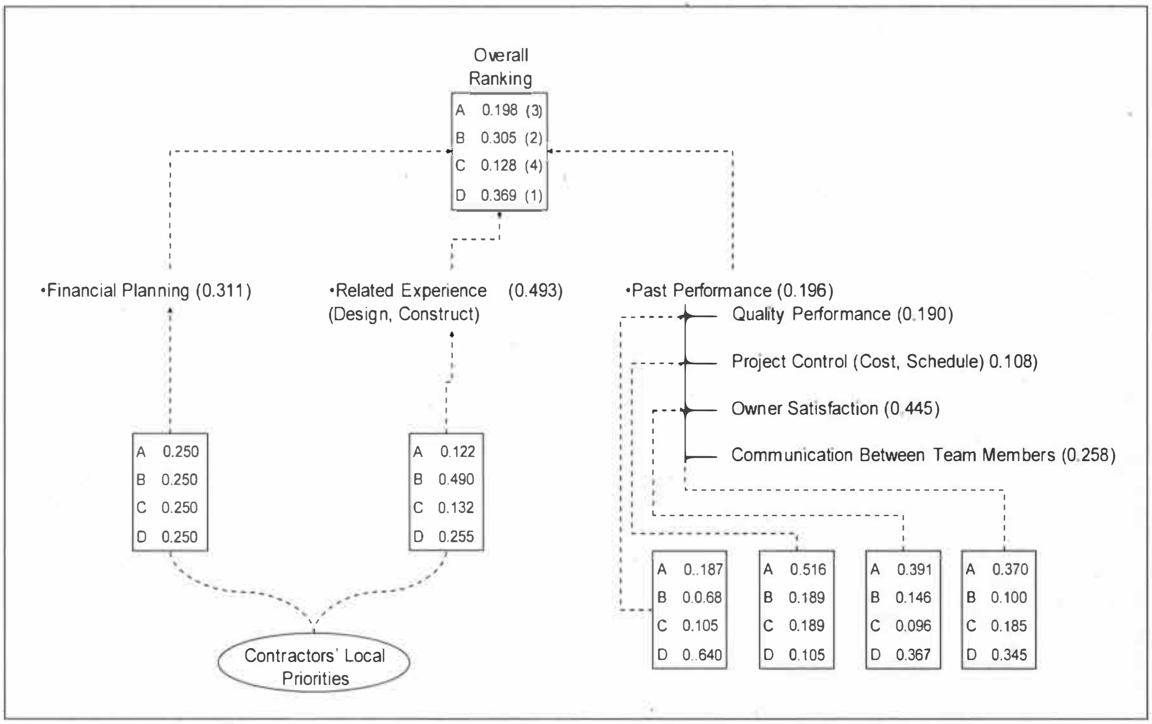

Figure 23: The Hierarchy, Local Priorities, and the Overall Ranking of Contractors (Warranty)

The overall ranking and the relative weights of the criteria, as provided by Expert Choice's interface, are provided in Figure 24.

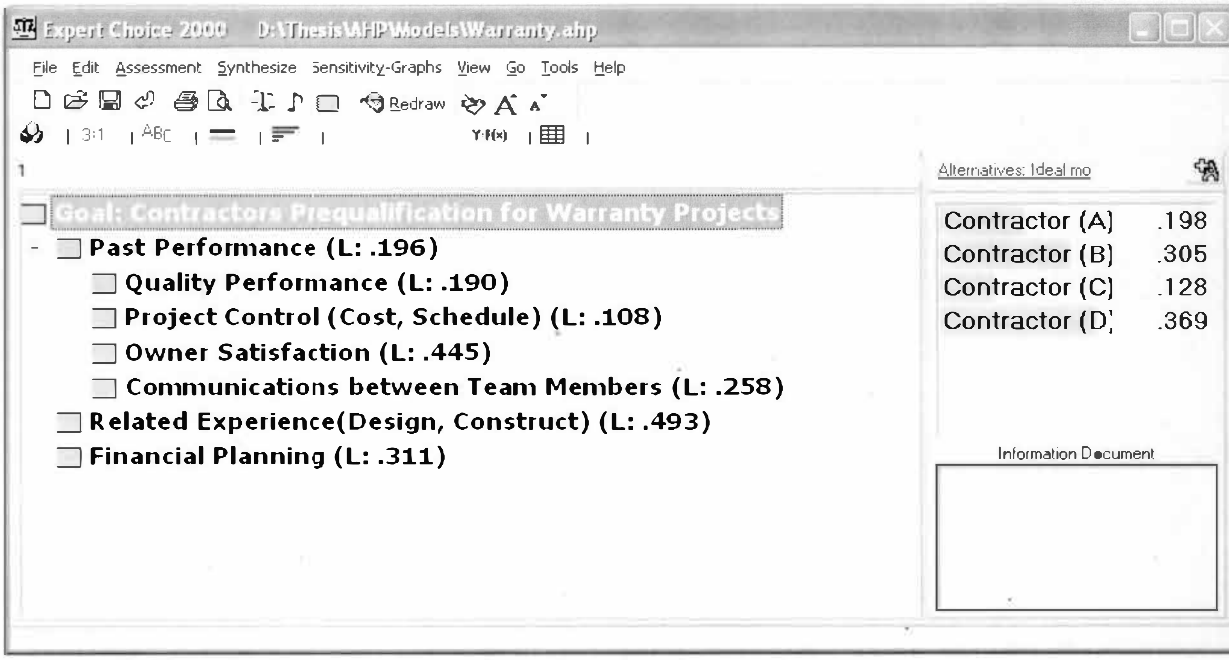

Figure 24: Expert Choice's Output Interface for Warranty

Chapter Seven

Closure

7.1. Summary

This study presents a prequalification model to screen contractors who want to submit low-bids on public projects using any of the three innovative contracting methods: Design-Build, Cost-Plus Time, and Warranty. This model was developed after a thorough investigation of the current prequalification practices and criteria under the traditional low bid method. The characteristics of the innovative contracting methods were studied to determine the qualifications that the contractors need to have in order to successfully deliver projects. The Analytical Hierarchy Process (AHP) was used to make prequalification decisions when multi criteria are used. Eventually, three case studies were used to test the application of the AHP to the prequalification criteria of the three innovative methods.

7.2. Conclusions/Recommendations

The study has reached the following conclusions and recommendations:

- Prequalification of contractors is very essential to increase the probability of delivering successful projects. Prequalification is more important for innovative contracting projects since these projects require emphasizing the existence of some qualifications: past performance, project understanding, financial stability and capacity, related experience, manpower and equipment, and financial planning.

- Combining low-bid selection method with any of the innovative contracting methods will give the best results only if competent prequalified contractors are bidding on the job. Otherwise, incompetent contractors will submit the lowest bids that are not based on true knowledge to carry on with such projects. This will cause them to fail.
- Establishing project-related, well-weighted prequalification criteria is significant to the efficiency of the prequalification process. The criteria should consider the special requirements of the innovative contracting method used to deliver the project. The weight assigned to each criterion should represent the importance of this criterion in the opinion of the criteria developers.
- The AHP effectively facilitates weight generation of the prequalification criteria. It helps in decomposing the prequalification criteria into a hierarchy that provides a deeper understanding of the criteria. It also makes decision-making easier and less subjective, especially when unquantifiable criteria are to be assessed.

7.3. Contributions

The study has made the following contributions:

- A prequalification model for low-bid public projects delivered under any of the three innovative contracting methods under consideration. It is a model that still uses low-cost bidding as the only criteria in the final selection of contractors, but it assures that only competent contractors will reach the final bidding process after being screened through the prequalification process.

- Establish two-step prequalification criteria that are related to each innovative contracting method. These criteria include the major success factors that can greatly contribute to the contractors' success. Some of the criteria such as financial stability, bonding capacity, and manpower and equipment are investigated only in the first step. This will prevent large contracting companies from dominating the market. Other criteria are investigated in both steps. Comparisons are made between contractors in the second step to rank them according to their qualifications.
- Utilize the AHP as an effective prequalification decision-making tool that eliminates subjectivity and produces decisions built on consistent judgments. [Software packages, such as Expert Choice] allow easier usage of the AHP. Prequalification team(s)' members can now focus on assessing and comparing the contractors' qualifications rather than performing mathematical operations.

7.4. Future Research

The following areas are possible future research that can support and enhance this study:

- Testing the model against more real-life case studies. These studies will be of greater use if they have data that can be run on all of the model components from annual prequalification through opening low-bids.

- Developing a database system for construction project information that records the performance of the winning contractors. The database can be of great use for the public agencies for future generations of prequalification criteria and their weights.
- Developing final prequalification/disqualification criteria to be applied to the ranked contractors. It can be based upon statistical inference of the past performance of contractors.
- Investigating legal issues regarding the implementation of this prequalification model. Phrasing the bidding documents and Request for Proposals can be a major field of research.

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