Value-Bidding: An Integrative Approach Utilizing Conjoint Analysis and Classical Bidding Theory

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ABSTRACT

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This dissertation is a unique treatment of competitive bidding theory. The methodology presented here utilizes an established marketing research methodology, Conjoint analysis, to establish the probability of winning based on multiple factors. This hybrid model, Value-Bidding, refocuses the competitive bidding model from fee-based selection criteria to value-based selection criteria. The resulting analytical model enables engineers to analyze market conditions, evaluate owner's priorities, systematically track competitors, and optimize job proposals, while maximizing the probability of winning, maximizing profit and optimizing price.

Traditionally, competitive bidding theory models the lowest-bidder-wins scenario, and the probability of winning is based on the probability that the bidder's price is lower than the competitors. (Friedman, 1956; Gates, 1967) Though this is a reasonable model for construction services, the fee-based competitive bidding models are not applicable for engineering design services. The selection criteria for engineer services often involves several factors, such as quality, availability, reputation, resume and references, and may or may not include price. From preliminary interviews, the author concluded that there is

a need for a systematic method of evaluating potential engineering job opportunities and determining fair market prices.

The goal of this dissertation is to inject science into the art of pricing engineering services. Value-Bidding is broad in scope and can address the process of selling multi-faceted services or products in a competitive environment. Value-Bidding supports the:

1) Definition of services
2) Evaluation of potential competitors
3) Evaluation of the probability of winning

The result of this research can support broad business decisions or service, product and price development for individual job proposals. In addition, the Value-Bidding methodology helps engineers optimize their technical and price proposals to meet business objectives, such as profit maximization or market expansion.

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Dedication

To my parents, Keith and Shirley Sturts,
for giving me the inclination to question,
the eagerness to comprehend,
and the freedom
do so.

To my love, Stephen Dossick,
for inspiring
confidence, courage and comfort.

To my new parents, Phil and Jane Dossick,
for your enduring
enthusiasm, encouragement, and esteem.

Chapter 1

Introduction

"Somebody is going to have to get good at selling"

- *Hank Harris, VP of Engineering and Architecture, FMI Corp., Raleigh, NC*

1.1 Introduction

The pricing of any creative service, such as creating corporate logos, designing bridges, decorating interiors, or developing museum exhibits, has always been subjective and market driven (Goodowens, 1996). Notoriety, popularity, and firm image increase prices, while standardization and commoditization cause prices to fall. There is often the question in the customers' minds, what are we paying for? What do we get for our money?

This dissertation addresses the issue of the pricing for engineering design services, particularly in light of recent and future technological developments, which drastically affect work flow efficiencies and the end product.

First, we must define what we are selling: engineering design services. The design of large engineering projects, bridges, tunnels, water systems, structures, power production plants, distribution systems, and industrial complexes require not only technical expertise, but a sense of good design. A good design is difficult to measure and includes metrics such as constructability, operations and maintenance cost, location and layout, power consumption, etc. (Sriram, 1998). Though clients receive drawings and specifications as an end product, the content of the design is the product of real value. On many civil engineering projects, at least one third of the design is completed by the time pencil meets paper (Fredrickson, 1998), and the preliminary decisions have the greatest impact on cost later on in detailed design, construction and operations and maintenance.

Ram Sriram, the group leader with the NIST Engineering Design Technologies Group, offers a description of the process of design in his editorial on Information Technology in the July 1998 Issue of the Journal of Computing in Civil Engineering:

> "Design is a process that constructs a description of an artifact, process, or instrument that satisfies a (possibly informal) functional specification, meets certain performance criteria and resource limitations, is realizable, and satisfies criteria such as simplicity, testability, manufacturability and reusability; the design process itself may also be subject to certain restrictions such as time, human power, and cost." (Sriram, 1998)

A guide published by the Engineers Joint Contract Documents Committee in 1995 presents a more legal definition of a design professional's duties (Engineers, 1995), which include:

- Advice to owners on technical and regulatory issues.

- Development of conceptual documents.
- Preparation of technical specifications and criterion.
- Assistance during construction and start-up.

The design process contains elements of both science and art. There is science in the engineering and art in the design. Since engineering design is a complex combination of services and products, art and science, a single unambiguous way to set prices for this industry does not exist. Engineers rely heavily on industry standards, and establish their prices in relation to these standards. They try to set themselves apart from the competition with unique approaches and services, while presenting competitive prices (Ismail, 2000). Consequently, industry standards and methods are continually being developed and redefined, while tradition and law has shaped the way engineers do business.

It is the author's belief that in light of the technological revolution we are now experiencing, the pricing of engineering services is at a critical point. Computers have revolutionized the way engineers do design (Benz, 1995, and Phair and Powers, 1998), and the Internet is changing the way engineers do business (Summit on Software, 2000). Due to the recent developments in computer-aided design and integrated databases, engineers have been struggling with the problem of how to charge for their services when an industry standard does not exist (Tulacz, 2000, and Vest and Crown, 2000).

The above discussion leads to the question: How do engineers price their services? More importantly, how will they continue to price engineering design as technology impacts the productivity of the industry? This dissertation attempts to address this question. The author suggests that the more valuable engineers can make the design to the owner, the more the design should be worth, and the higher fee they can and should charge.

1.2 Research Scope and Associated Areas

In the civil engineering industry, contract awards may be based upon considerations other than price (Frey, 1999). In fact, the Brooks Act outlined in the Federal Acquisition Regulation section 36.6 stipulates that the selection of engineering and architectural services must be based on demonstrated competence and qualifications with fair and reasonable fees, and that fee bidding is illegal (FAR 2000). Proposals for engineering services generally include a statement of qualifications, the proposed technical approach, and a fee proposal (Parks and McBride, 1987).

Since the selection process is based on more than price, there is a need in the industry for a methodology to capture the owners' values and preferences when selecting engineering services. Though there exists an informal exchange of information between clients and designers (Roy, 2000), there is no formal methodology used to characterize the attributes of the design service that owners find most valuable and incorporate this knowledge into the proposal development process.

The models presented in this dissertation are designed to help architects and engineers develop winning proposals and quantify their chances of winning in a quality-based bidding environment. The fundamental assumption is that instead of bidding solely on price, engineers compete on the perceived value of their services. Therefore this bidding model shifts the focus from a lowest fee criterion, to a more complex and subjective criterion based on multiple factors.

The author has adopted the term Value-Bidding as a combination of the concepts from value pricing and competitive bidding. This methodology aligned with the idea of value pricing as it is presented in the marketing literature (Nagle and Holden, 1995, and Stasiowski, 1993). Professional organizations and proposal consultants often recommend that engineers base their price proposal on the owner's preferences (Blake, 1997; Quick, 1992; Sturts, 2000), however there has been limited methodology presented to quantify this type of information.

The Value-Bidding analysis is a formal methodology whereby engineering designers can evaluate their services in terms of fundamental attributes or aspects and determine which attributes are most valuable to their clients. The key part of this research is the integration of the marketing research, (conjoint analysis) with the pricing strategy for design services. In this process we examine the qualities of a design service that owners consider valuable and estimate the weight owners place on each attribute. (These weights may vary across industry sectors and types of owners.) We then combine this marketing research with a bidding model to produce an optimum proposal package, which is tailored to the interests of the owner.

In this cross-disciplinary research, the author draws from the following disciplines: engineering design, construction engineering, and business marketing. Engineering design services are analyzed, and construction-bidding theory is modified to incorporate choice-based conjoint analysis. Conjoint analysis has been developed extensively in the marketing literature (Green and Srinivasan, 1990; 1987).

Though the methodology developed in this thesis is to solve the specific problem of developing proposals and fees for engineering design services, it is the author's belief that this methodology can be generalized to any industry where the procurement process is similar. The theory described in this dissertation can be applied to any market where firms compete for clients, and price is not the only deciding factor in the procurement process.

1.3 Motivation for Research

This section briefly introduces the impetus for this research, and these issues will be covered in complete detail in Chapter 2 of this thesis. The motives behind this research fall into the following categories:

1. Research in construction and information technology

2. State of the marketplace

3. Lack of current methodology

1.3.1 Research Backdrop

The author has been involved with a research program to investigate the use of three-dimensional computer models and associated databases in construction engineering processes. In the context of this research, it was determined that much of the model development and database integration must be established during the design phase of the project (Griffis and Sturts, 2000). Consequently, it is necessary for the owner to encourage the development of three-dimensional models, and integrate these models with other project databases. Designers must also invest in resources to facilitate this technology. Partnerships between owners, designers and constructors can often facilitate the use the information technology throughout the project process.

The results of the research outlined in this dissertation are intended to assist in the pricing of information technology development. Furthermore, designers as well as computer systems engineers can utilize the output of this methodology to develop computer systems that meet the owners' requirements.

1.3.2 State of the Marketplace

As software systems become more sophisticated, the market for design services and the products of engineering design is changing (The Summit, 1999). The more sophisticated users of CAD, such as designers in the process and power industry, are working with three-dimensional computer models, and owners in this sector are beginning to emphasize the need for data-centric models (Phair and Powers, 1998). An engineer from the building industry summed it up in his remark that "some people are still focused on selling engineering hours and drawings, but the real product is the building." (Widman, 2000) Owners vary in their needs and in their evaluation of those needs. Using the theory presented here, engineering designers can assess the technology that the owner considers valuable, determine how valuable the owner perceives this technology to be, and develop a competitive proposal incorporating this knowledge.

Futhermore, the procurement process is changing for both design and construction. While design/build projects have brought designers and constructors together to bid jointly for projects, some private and public agencies are turning away from lowest bid procurement policies (Low Bid, 1998). Some owners have found that lowest bid contracts tend to prompt cost overruns and litigation, while cost cutting procedures reduce quality and may increase overall project cost, e.g., increase maintenance and early replacement costs. Alternative procurement policies are being tried across the country. For example, owners are also looking to incentive/ disincentive contracts to reward consultants for saving the owner in construction cost and increasing the speed of design or construction, as well as penalizing them for holding up the job in any phase of the project (Low Bid, 1998).

In theory, many owners prefer quality-based selection to the lowest fee selection criterion. However, some owners tend to focus on price, particularly when the market is weak and funding is limited. Selection committees are often obligated to justify contracting a higher priced firm. If this justification is not evident, the committee is bound to choose the competitor with the lowest price (FAR 15.101). Nevertheless, many have presented arguments against low fee selection practices, and encourage owners to weigh the value of the services presented against the fee proposed (Hampton, 1994). Furthermore, many procurement procedures require the design firms be selected based on qualifications (FAR 2000) with the fee negotiated in the second phase. This provides the design firm ample opportunity to justify their fees.

Several articles in professional magazines such as ASCE's *Civil Engineering* give evidence of a shift in procurement philosophy of public agencies. In Chapter 2 there is a discussion of two case examples from the Maine DOT and the Florida DOT. For many services, (not just design services), these public agencies are shifting the focus from a primarily price-based selection criterion to a more qualification-based selection. In general, quality-based decision-makers weigh the technical proposals by the price, and sometimes associate low price with low quality (Phipps, 2000, and Low Bid, 1998).

1.3.3 Lack of Existing Methodology

Bidding models in the civil engineering literature focus on bidding for construction contracts (Benjamin, 1972; Griffis, 1992; Christodoulou, 2000). For construction contracts, the competition is based primarily on price (Christodoulou, 1998); however, as was mentioned above, for the selection of architectural and engineering contracts, price is often not the only factor (Veshosky, 1994; FAR, 2000). Though price is not completely absent from competition among design engineers, there are other factors, such as quality and technical expertise that play a role in an owner's choice for design services. These other factors are not addressed in the current state of the art of bidding theory, and this dissertation addresses this issue.

1.4 Dissertation Objectives and Research Methodology

The objective of this research is to provide a methodology for the civil engineering industry to facilitate the development of competitive fees based on the value of the service rendered. The procurement of engineering design services is more complicated in that the selection process is not always solely based on price (Slater, 1998, Phipps, 2000).

Generally there are two stages of a quality-based bidding process:

1) Creation of a short list based on qualifications (sometimes with respect to fee).

2) Fee is negotiated between owner and design firm

An attempt is made here to combine choice-based conjoint analysis with bidding theory to establish a new bidding scheme: Value-Bidding. This methodology is particularly relevant when price is not the sole deciding factor in the selection process. Specifically, choice-based conjoint analysis provides users with choice probabilities - the probability that an alternative will be chosen, given a set of attributes and alternatives.

Then, concepts are adopted from the competitive bidding models, (which have focused primarily on the construction industry bidding scenarios.) In bidding theory, one develops probability distributions for the likelihood of winning over a competitor. Past theoretical developments have focused on probabilities that are developed from competitor's markups given their bidding history (Christodoulou, 2000). Value-Bidding analysis extends this idea, and distributions must be developed for factors such as past experience, quality, responsiveness, as well as proposal price. There are three potential types of competitors.

1) Known competitors
2) Average competitors
3) Unknown competitors

Finally, the competitor profiles and the conjoint probability of winning are combined to determine an overall probability of winning. This overall probability of winning given known, average and unknown competitors can be used in a variety of ways in evaluating the proposal process and defining proposal and business goals.

1.5 Dissertation Organization

In this first chapter, we introduced the problem of submitting proposals for engineering design services. The research scope was defined along with the motivation for this research. The dissertation objectives were outlined as the development of a Value-Bidding Model, which incorporates aspects of design services into the optimization of proposal development. This methodology incorporates aspects of conjoint analysis from the marketing literature with the state of the art in construction competitive bidding theory.

Chapter 2 develops the motivation for this theoretical development. The author's interest in this area of research grew from her work with the use of three-dimensional computer models and associated databases for the management of construction. Furthermore, the current state of the market emphasizes the need for the methodology presented in this dissertation. Quality-Based selection and the demand for high tech services illustrate the market's influence on a firm's probability of winning design contracts. Consequently, there is a need to incorporate the owner's perspective in the proposal development process.

Chapter 3 introduces competitive bidding theory. After the introduction, Section 2 presents the background literature review, while Section 3 presents details on the state of the art in the determination of the probability of winning. Section 4 presents the bidding models used in this dissertation and presents the arguments behind their usage.

Chapter 4 introduces conjoint analysis. The literature review is presented with emphasis on choice-based conjoint analysis, and the arguments for choice-based conjoint analysis are developed. Finally, the models used in this dissertation are described.

Conjoint analysis and bidding theory are combined in Chapter 5, the Value-Bidding Model. The model development is presented, and key aspects highlighted. Chapter 6 suggests the different competitor types one can model, e.g., known competitors, average competitors and unknown competitors. Before the detailed analysis is conducted, the firm must decide whether to submit a proposal for a given job. The author proposes a decision metric to support this decision based on Value-Bidding estimations and within the context of the following goals.

1) Win the job
2) Gain entry into new geographic or technical territory
3) Maximize profit

Chapter 7 addresses the decision to submit a proposal or not, a selection process without fee, and a selection process with fee all in relation to the goal of winning the job, and the details relating to the goal of entering a new territory are presented at the end of Chapter 7. The third goal, maximizing profit, is addressed in Chapter 8. The case study, described in Chapter 9, illustrates the flexibility and wide range of application of the Value-Bidding tools. In summary and conclusion, Chapter 10, the author discusses the models' potential applications and limitations, as well as the implementation issues.

References

Bechtel, (1999) Personal Correspondence.

Benjamin, Neal B.H., (1972), "Competitive Bidding: The Probability of Winning", Journal of the Construction Division, ASCE, Vol. 98, No. ST9, September, pg. 313-330.

Benz, Stephen M., (1995) "What do project Managers Need to Know about CADD?", Journal of Management in Engineering, Jan/Feb., 1995.

Blake, Gary, (1997) "8 Tips to Writing Better Proposals," Civil Engineering News, Nov. Issue.

Christodoulou, Symeon, (2000) "The Science in Human Intuition: Optimum Bid Markup Calculation in Competitive Bidding Environments Using Probabilistic Neural Networks", working paper.

Christodoulou, Symeon, (1998) "Optimum Bid Markup Calculation In Competitive Bidding Environments Using Fuzzy Artificial Neural Networks", Ph.D. Thesis, Columbia University, New York, New York.

Engineers Joint Contract Document Committee, (1995) Standard General Conditions of the Contract Between Owner and Design/Builder, Professional Engineers in Private Practice, a practice division of the National Society of Professional Engineers, American Consulting Engineers Council, and the American Society of Civil Engineers.

FAR, (2000) Secretary of Defense, Administrator of General Services and the Administrator, National Aeronautics and Space Administration. "Federal Acquisition Regulation," Published by GSA's FAR Secretariat on Behalf of DoD, GSA, and NASA, http://www.arnet.gov/far

Fees '98, 1998 Fees Survey, Orinda, CA, Guidelines, 1998.

Fredrickson, K. (1998) "Design Guidelines for Design-Build Projects," Journal of Management in Engineering, vol. 14, no. 1, pp. 77-80, January/February 1998.

Frey, Robert S., (1999) Successful Proposal Strategies for Small Business: winning government, private sector, and international contracts, Second Edition, Artech House, Boston, 1999.

Goodowens, James B., (1996) A User's Guide to Federal Architect-Engineer Contracts, 2nd Ed., ASCE Press, New York, NY, 1996.

Green, Paul E., and V. Srinivasan, (1990) "Conjoint analysis in Marketing: New Developments with Implications for Research and Practice," Journal of Marketing, Oct. 1990, pg. 3-19.

Green, Paul E., and V. Srinivasan, (1978) "Conjoint analysis in Consumer Research: Issues and Outlook", Journal of Consumer Research, Vol. 5, September 1978, pg. 103 – 123.

Griffis, F.H. (Bud), (1992), "Bidding Strategy: Winning Over Key Competitors", Journal of Construction Engineering and Management, ASCE, Vol. 118, No. 1, March 1992, pg. 151-165.

Griffis, F.H. (Bud), and Carrie S. Sturts, (2000) Three-Dimensional Computer Models and the Fully Integrated and Automated Project Process of the Management of Construction. A Report on Best Practices, Construction Industry Institute, Research Report 152.

Haaijer, M. E., (2000) "Modeling Conjoint Choice Experiments with the Probit Model", Ph. D. Thesis, University of Groningen, The Netherlands, 2000, http://www.ub.rug.nl/eldoc/dis/eco/m.e.haaijer/

Hampton, Delon, (1994), "Procurement Issues", Journal of Management in Engineering, November/December, 1994, pg. 45-49.

Ismail, M.H., Personal Interview, STV Group New York Office, October 2000.

"Low Bid Gives Way to Mid-Bid", (1998) Civil Engineering, pg. 10-11.

Nagle, Thomas T., and Reed K. Holden, (1995) The Strategy and Tactics of Pricing: a guide to profitable decision making, Second Edition, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1995.

Parks, Gary A., and Robert R. McBride, (1987) "Competitive Bidding for Engineering Services", Journal of Professional Issues in Engineering, Vo. 113, No. 1, January 1987, pg. 66-76.

Phair, M., and Mary B. Powers, (1998) "Processing Data", Engineering News Record, McGraw-Hill, August 31, 1998.

Phipps, Alan R., (2000) "Box Girder Balancing Act", Civil Engineering, ASCE, March 2000, pg. 33-39.

Quick, J., (1992) Dog & Pony Shows: How to Make Winning Presentations When the Stakes are High, McGraw-Hill, New York.

Roy, David (2000), Personal Interview, CII research meeting in Houston, Texas, October, 2000.

Slater, T.S., (1998) "Quality Based Selection in Design-Build Environments: 'How Can QBS Work for You?'", Journal of Architectural Engineering, March 1998, pg. 1-2.

Sriram, Ram D., (1998) "Information Technology for Engineering Design", Journal of Computing in Civil Engineering, July Issue, pg. 123-125.

Stasiowski, Frank A., (1993) Value Pricing for the Design Firm, John Wiley & Sons, Inc., New York, 1993.

Sturts, Carrie S., (2000) Appendix A. from Construction Planning for Engineers, by F.H. (Bud) Griffis, and John V. Farr, McGraw Hill, New York, 2000.

"Summit on Software Reveals the Changing Role of Technology", (2000) Civil Engineering, March, 2000, pg. 32.

"The Summit on the Future of Engineering Software: Whitepaper", (1999) Cad Society Meeting, Chicago, Nov. 8, 1999, http://www.cadsociety.org/summit/whitepaper.htm

Tulacz, Gary J., (2000) "Hot Markets Shift Into Higher Gear", Engineering News Record, April 10, 2000, pg. 56-64.

Veshosky, David, (1994) "Portfolio Approach to Strategic Management of A/E Firms", Journal of Management in Engineering, Sept./Oct. Issue, pg. 41-4.

Vest, David and David Crown, Personal Telephone Interview, CH2M Hill, November, 2000.

Widman, Sam (2000), Personal Interview, Ammann & Whitney New York office, December, 2000.

Chapter 2

Motivation for Theory Development

"Managing a CADD-based design project requires the project manager to rethink the entire design process."

–Stephen Benz, P.E., President of
Benz Automation Consulting,
Wrentham, Mass.

2.1 Introduction

Pricing is not an exact science. Counter to classic engineering training, pricing is not deterministic, not codified, and more profitable pricing decisions are not always the obvious ones. Some of the non-quantifiable influences include the owner's perception, engineer's need for work, prestige of a job, and the state of the market. Engineers prefer to use mathematics and physics to calculate deterministic answers. Beam sizes, piping sizes, electrical voltage requirements are all treated as deterministic problems. Consequently, engineers are rarely trained to sell their services; they are trained to design safe and reliable engineered systems. Engineering managers learn on the job how to manage costs, set prices and negotiate contracts. Furthermore, historically, marketing one's professional services was viewed as unprofessional. As recently as the 1970s, many fought against self-laudatory statements and corporate logos. (Peck, 1994) Engineers relied upon their ethical and technical reputations and focused on the technically challenging and interesting aspects of the design profession. Today, engineers are recognizing a need for marketing, and marketing strategies are becoming a major component of an engineer's job. (Marines and Rose, 1998; Smallowitz and Molyneux, 1987)

The problem of pricing engineering services is not so much where we are today; it is where we are heading tomorrow. Technology is revolutionizing the way engineers work, and there is a need to revise the pricing strategies for engineering design services. (Tippett and LaHoud, 1999) The industry dilemma can be summarized from two perspectives. First. the pure pricing problem entails the difficulty of justifying a price for professional services. The second is a perception problem, where engineers are not perceived as professional service providers, but rather, as technical experts who follow industry guidelines. (Engineering, 1995; Bachner, 1991)

2.1.1 The Pricing Problem

Expertise, creativity and quality are difficult to quantify. These are aspects of engineering design as well as the more technical facets of stability analysis and drawing production. One industry standard is to develop a price for engineering services based on labor-hours: estimated labor-hours per drawing, and estimated labor-hours based on project schedule. However, some engineers and most architects argue that expertise and creativity cannot be measured in labor-hours. (Parks and McBride, 1987)

Information technology is speeding up the process of engineering design. If a design firm charges based on time, as project durations get shorter, revenues decrease. (Stasiowski, 1993) Technology-enhanced design products and productivity improvements are making pricing based on time obsolete. Though other pricing schemes, such as value pricing, have been presented in the literature (Stasiowski, 1993), there has not been, in the author's opinion, a methodology presented to implement such schemes. The engineering industry needs a new methodology to determine what the clients deem valuable, what aspects of the services they are willing to pay for, and how valuable they perceive these aspects to be. Furthermore, engineers need a technique in which they can incorporate this knowledge into successful proposals for design services.

A second and older method of pricing is to estimate the design fee based on a percentage of construction costs. As a result of the non-quantifiable duties of a design engineer, a common method of developing contract fee schedules is to scale the price of design services based on the more quantifiable estimated cost of construction. Regulations and guidelines in the public and private sectors (Townsend, 1988, and Fees '98) outline a detailed schedule of design fees based on the estimated cost of construction. These guidelines range from 6% to as high as 18% of construction. The guidelines include multipliers for complexities such as survey requirements, matching present materials, more frequent consultations, etc. There are also reduction factors for simplicity, such as warehouses or parks.

Design/build contracts are a natural extension to this pricing methodology. Generally, design/build fees are lump-sum contracts and the design fee is absorbed as part of the project package. Industry sources indicate that firms that bid for design/build contracts estimate the construction costs and add on 7% to 12% of the estimated construction cost to cover design costs (Vest and Crown, 2000).

Though the percentage of construction costs method of determining a design fee is more aligned with a value pricing philosophy, construction costs do not necessarily reflect the value of the design. Furthermore, depending on the contract structure, there is not necessarily a financial incentive for engineers to save on construction costs, or design an efficient building. Though engineers take pride in their profession, and are encouraged to pursue safety and uphold a high level of quality that reflects well on the profession as a whole (NCEES, 2000; ASCE, 2000), engineers are also in business to make a living. They can and will go above and beyond the call of duty, as long as it makes financial sense. Consequently, engineers should attempt to price their services based on value-added attributes, as well as traditional market value methods. This dissertation presents a methodology to assist in this process.

2.1.2 The Perception Problem

As discussed in Chapter 1. the Brooks Bill declares that it is illegal to conduct a competitive bid for engineering and architectural services by agencies using federal funds. However. it is evident from the literature (Hatheway. 1995: Trigueros. 1995: Tulacz. 2000) that many owners weigh the bid price heavily when choosing a firm for design services.

Some design engineers claim that bid shopping has been detrimental to the civil engineering profession. (Hatheway. 1995; Trigueros. 1995) Fee-based proposal selection reduces the profession to a technical level. where the engineers no longer are the creative and inventive professional service providers they once were, but are now focused on creating a design as efficiently as possible. which may be to the detriment of quality. to maintain a profit under competitively low fees. Critics argue that under a fee-based procurement environment. engineers are no longer able to create good designs; instead. they tend to create the minimum that is required. (Parks and McBride. 1987) Furthermore. poor quality designs (including interferences. omissions and inefficient specifications) create an antagonistic relationship between the owner and designer. as well as the contractor and other project participants. which in turn. may lead to costly disputes.

Since the 1950s. there has been a drastic change in the image of the engineering design profession as a whole. (Bachner. 1991) Where in the past. engineering design had the clout of an established profession with a code of ethics and close professional-client relationships, in today's market, for a number of reasons outside the scope of this discussion (Bachner, 1991), engineers have lost this sense of professional distinction. Consequently, many feel that engineering design is undervalued in the marketplace (Parks and McBride, 1987; Hatheway, 1995). As Allen Hatheway laments in ASCE's Civil Engineering magazine: clients assume "that the qualifications of all bidders are equal and that only the quoted price is important." Many feel that engineering design services have become commodities. (Trigueros, 1995). A commodity is a product or service that is relatively equal in quality across all providers - products such as milk and eggs, or services like dry cleaning, phone service and shipping. The industry image in many sectors is that engineering design quality is standardized, and engineering expertise and creativity is overlooked in a competitive procurement environment.

It is the author's opinion that the attention on the price of design is misplaced in light of the designer's influence on total project cost. The design is generally only about 6-9% of the construction cost (Townsend, 1988; Fees, 1998; Veshosky, 1994), which means that design is somewhere between 1.5 % of the total project cost for a building, and as much as 5% for an industrial project. (Hampton, 1994) Furthermore, the designer has the ability to save the owner money in procurement, construction, operations and maintenance, through good design and value engineering (Griffis and Farr, 2000). The planning and design phases are the primary influences on construction cost and schedule:

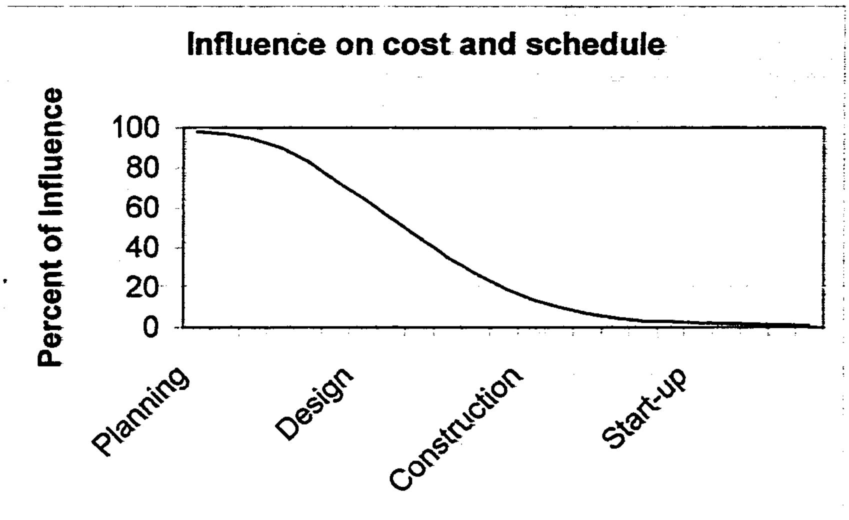

Figure 2.1 The Degree of Influence Project Participants Have on the Construction Cost and Schedule (Griffis and Farr, 2000)

If an owner hires a designer through a fee-based competitive procurement process, the engineers most probably will not spend the time necessary to make the design as efficient as possible. (Hatheway, 1995) It has been observed, that price-based procurement of design services can lead to excess construction and life cycle costs (Hampton, 1994), because the designers tend to minimize costs and do not spend the extra effort to create the most efficient and effective design. Consequently, many encourage the use of quality-based selection to obtain the greatest value per dollar spent on engineering design. (Hampton, 1994; Hatheway, 1995 and 1996; Trigueros, 1995; Parks and McBride, 1987, and others)

The models presented in this dissertation attempt to build on the idea of quality based selection, and provide the practitioner with a methodology for capturing the aspects of the design services that are perceived as high quality, then developing a competitive design fee that reflects the perceived value of these design service aspects. This dissertation is an effort to reverse the trend: to encourage engineers to sell their services based on value.

2.2 Past Research in Construction and Information Technology

The problems stated above are complicated by the fact that information technology is revolutionizing the entire project delivery process. (Phair and Powers, 1998) The author has been involved in a research endeavor to establish the state of the practice and the future use of three-dimensional computer models and associated databases in the management of construction. In the process of conducting this research, it became clear that the development of the model influences its usage for procurement, construction and later phases (Griffis and Sturts, 2000).

In their research study, Griffis and Sturts also concluded that the three-dimensional computer model and associated databases should be developed to support the construction process. Construction engineers utilize models and associated data very differently than designers who develop them, and there are current and future research endeavors, which are attempting to define standards that benefit the design to construction transfer of three-dimensional computer models and associated databases. For example, designers often organize the model by component and associated fixtures, (e.g., a pump with the electrical, instrumentation and piping requirements). However, a constructor often separates the design by trades and would be more interested in all electrical requirements in a certain section. (e.g., all electrical components in the south west quadrant). Since it has been shown that the use of three-dimensional computer models on the construction site reduces project costs when used adequately in the construction phase. (Griffis, et.al., 1995), there is a need for a change in the design process whereby constructors are involved in model development so that they can determine what is necessary to support construction processes. It is in the owners' best interest, therefore, to encourage the development of a three-dimensional computer model and associated databases to support construction, operations and maintenance.

In light of these technological developments and requirements, design engineering processes and will change considerably as computer technology becomes mainstream. The author recognizes that the market place is a very complex process to model, and has chosen to focus on the design services procurement process. The methodology presented in this dissertation is aimed at presenting designers with a theory, and models that will assist them in their efforts to understand the factors that are driving the market and the technological developments that owners deem valuable.

2.2.1 Information Technology Changing the Design Process

The technology utilized in the preliminary design phase influences the entire project. As project databases are integrated, and project process automated, the development of a project computer system should be initiated in the pre-project and design phases. (Griffis and Sturts, 2000) Consequently, throughout the civil engineering industry, the design deliverables are changing from two-dimensional drawings and written specifications, to a three-dimensional computer model and potentially integrated databases and specifications. Some sectors are farther down the three-dimensional computer model path then others, but many in the industry foresee three-dimensional computer models as the way of the future (Phair and Powers, 1998).

Computer-aided Design (CAD) has been hailed as one of the most influential engineering design productivity enhancing tools of the century. (The Summit, 1999) Though users have realized limited productivity gains with two-dimensional CAD (Stasiowski, 1993), engineers who use three-dimensional designs are realizing vast efficiencies in terms of labor hours needed for a design project. Historically, design offices would cover floors of office buildings with drafts people. Where in the past, some projects required hundreds of people designing and drafting in two dimensions, now these same projects require only 10% of the number of people working in three-dimensions on personal workstations. (Smith, 2000) The software is continually improving, and efficiencies are only going to increase. Moore's Law, named for Gordon Moore, states that every 18 months computing power doubles. His law has been true for over 20 years, and is predicted to continue at least thru 2010. (Moore's Law, 1999) Consequently, as Donald Trippet, engineering professor at the University of Alabama, and Paul LaHoud, Chief of the Civil-Structures Division and Chief of Design at the US Army Engineer Support Center, point out: "The CAE [Computer Aided Engineering] technology will lead to a reduced staff size and composition. This will require a significant revision to costing strategies for services." (Trippet and LaHoud, 1999)

For example, computer usage and CAD enables:

1. Easy design revision. Consequently, revisions are more common and more numerous than in the past. (Widman, 2000; Harris, 2000)
2. Computerized design analysis (such as, Finite Element Analysis). Computer memory and calculation capacity, as well as readily available software packages, enable engineers to perform design analysis unheard of before computers.
3. Generation of two-dimensional drawings, customized views and sections. Depending on how it is set up, using a three-dimensional computer model, constructors can customize views and sections to answer their specific questions in terms of trades and at any level of detail.
4. Better quality designs in less time than in the past. Engineers and constructors can spend more time on constructability reviews, value engineering, and trade coordination in the design phase. CAD enables major design changes throughout the project.

Furthermore, three-dimensional computer models are just the beginning of the information technological revolution in the civil engineering industry, and the process and products of design services are changing. (The Summit, 1999) We have only to look at manufacturing and ship building industries to see the future of the design and construction of facilities, buildings and other civil works projects. Industry leaders in the process and power industry have begun using and are developing more sophisticated ways to use three-dimensional computer models and associated databases. As discussed in the Engineering News Record, more sophisticated owners are requiring data-centric design, instead of the more established drawing-based design. (Phair and Powers, 1998)

The business of engineering design will be vastly different in the future. For example, with the increase of Internet commerce, the specifications might be active web links to vendor pages and specifications. Web communication might automate procurement, and the vendor supply schedule and delivery. Industry leaders foresee the internet and data communication tools revolutionizing the industry (Griffis and Sturts, 2000), and research is ongoing to apply manufacturing techniques, such as Just-In-Time delivery, to construction projects. (O'Brien, 1998)

However, the more things change, the more they stay the same. The basic element of design, i.e., solving a physical problem such as creating a river crossing, or developing a family residence, will still involve human ingenuity and design decisions. The delivery of these ideas will change drastically in the future, but the act of creation will remain human, and the construction will always involve the transportation and coordination of labor, materials and equipment.

The challenge is to put a price on human ingenuity. How much is an engineer's solution worth? Today, to justify their prices, many in the design industry price their services based on the labor-hours involved in creating the design package. Since drawings, calculations and analysis were done by hand, engineering design was a labor-intensive industry. Computers have automated many engineering functions, but engineers are still basing their prices on labor hours. Therefore, for the most part, the engineering industry has passed the productivity produced by the electronic revolution to the owner. Though overhead rates have increased, managers are finding it difficult to account for the costs of technology and training in today's labor-based pricing scheme. In the an April, 2000 issue, Engineering News Record's Gary Tulacz reports on the top 500 design firms in the United States. He quotes David Evens, CEO of a design firm by the same name: "Selling hours is something we have to get away from… design no longer is a labor-intensive business. It is capital-intensive." (Tulacz, 2000)

Since design engineers have established a pricing policy based on labor-hours, logic necessitates that engineering fees will decrease as engineers utilize three-dimensional CAD capabilities and realize these efficiencies. However, the value that owners receive from design services is increasing. (Golish et al., 1993) The owners receive more today for the same amount of funds than they did in the past. (Tippett and LaHoud, 1999; Widman, 2000)

To maintain profitability throughout this time of technological transition, designers must be in touch with the needs and requirements of owners. Though many of these technical requirements are outlined in the request for proposals (RFP), the engineering design firms must anticipate the developments in their sectors and prepare their organizations to meet the technology demands of the future. The methodology presented in this dissertation will help engineers acquire knowledge that will assist them in this effort, and further, will present the engineering industry with a methodology to develop prices for new services inspired by the technology revolution.

2.2.2 Construction-Driven Design

Not only does recent technology change the way design firms work internally, but also the technology changes the interactions between designers, owner, contractor and potential suppliers, manufacturers and subcontractors. Electronic communication connections via the Internet enable virtually instantaneous interactions between the owner, designer and constructor. The designer can publish design files to the contractor, and receive revised shop drawings electronically. Standards and protocols are still being developed for this new communication media.

Not only are there efficiencies in the design process, but also integrated systems provide engineers and constructors with data from vendors, corporate databases and past projects. Potentially, automated systems could link design models with accounting, procurement, and document control systems, and telecommunication systems allow updates to be distributed world-wide within seconds.

Traditionally, designers provided drawings and specifications to the owner. The owner then could bid a project out for construction. The designer might also be hired for construction support: shop drawing approval, request for information (RFI) response, and existing condition(s) or redesign resolution. Now, many designers produce electronic models. These models introduce a whole new world of potential functionalities throughout the project life cycle. For example, three-dimensional computer models can be integrated with other project databases. With a 3D model one can:

- Integrate with other project systems, i.e., construction estimation, procurement and materials management.
- Generate 2D and 3D representations, component details, and customized views.
- The integration trade design and the coordination of independent design consultants would eliminate design conflicts between trades

Design influences the productivity of procurement, construction, and potentially, operations and maintenance. However, the design model should be created with procurement, construction and other project life-cycle applications in mind.

Owners can save money in the design phase by preparing the design to support construction. For example, the CII Research Team 106 showed that three-dimensional computer models save money in construction when used properly. (Griffis, et.al., 1995) This makes a construction driven design more valuable than the average design today. In the philosophy of value pricing, the designers should receive higher fees for a more valuable construction driven design. If the owner shares the cost savings with the designer, the designer has a financial incentive to produce a design geared toward cost savings in construction. The methodology presented in this dissertation will help designers quantify the value owners place on construction cost savings.

2.2.3 Conclusion Regarding Technology and Design

Technology is increasing the potential value of the engineering design products, i.e., the plans and specifications for construction of a facility, building, road, sewer line, etc. A three-dimensional model with associated database capabilities is much more valuable to an owner than a book of two-dimensional drawings. Three-dimensional computer models have greater potential to reduce the cost of construction compared to two-dimensional drawings and provide a basis for improving the operation and maintenance of the facility over its lifetime. Three-dimensional models enable the owner to save money down the line in construction, start-up, operations and maintenance (Griffis, et. al., 1995, Griffis and Sturts, 2000), and the price of the design services, which enable this cost savings, should reflect this value-added service.

Engineers should incorporate the value of the three-dimensional computer model and associated databases into the pricing for these services. The more valuable they can make the design to the owner, the more the design should be worth, and the higher fee they can charge (Berzins, 1989). Consequently, designers need to market their products and services as something different than the traditional drawing board designs. The focus of the industry is shifting from specialized design phase services toward life cycle services. (Marines and Rose, 1998)

The models presented in this dissertation are designed to provide the engineering design industry with a methodology for capturing the value of their services. This thesis involves the formulation of these new design services and the pricing foundations of these services. Inherent in the model is input from owners as to what aspects of design services they value and how much they are willing to pay for these aspects.

2.3 Current State of the Market

2.3.1 Contracting Strategies

The business of engineering is an old one. Many artifacts from past civilizations are civil works such as roads, canals, bridges, houses, and pyramids. Engineers have been planning and building cities since human beings began creating them. Though there have been advances and changes in engineering methodology, today's practices are based upon ancient traditions.

The evolution of the engineering professional practice began with the master builders who both designed and constructed engineering works. (Potter and Sanvido, 1994) As engineering became more mathematical, sophisticated and specialized, engineers began teaming up to work on projects, each bringing their own expertise to the table. The individual was replaced by organizations. The wealth of information, educational and training requirements, as well as business opportunities, motivated a change in the industry. Engineering design and construction specialties emerged, and construction became separate from design. With specialized firms, as opposed to the master builder model, owners usually hire a designer as well as a constructor. The designer in turn hires many subconsultants who specialize in one discipline of engineering, i.e., electrical, foundation engineering, mechanical, or structural. The contractor in turn will hire subcontractors who specialize in different trades of construction technology.

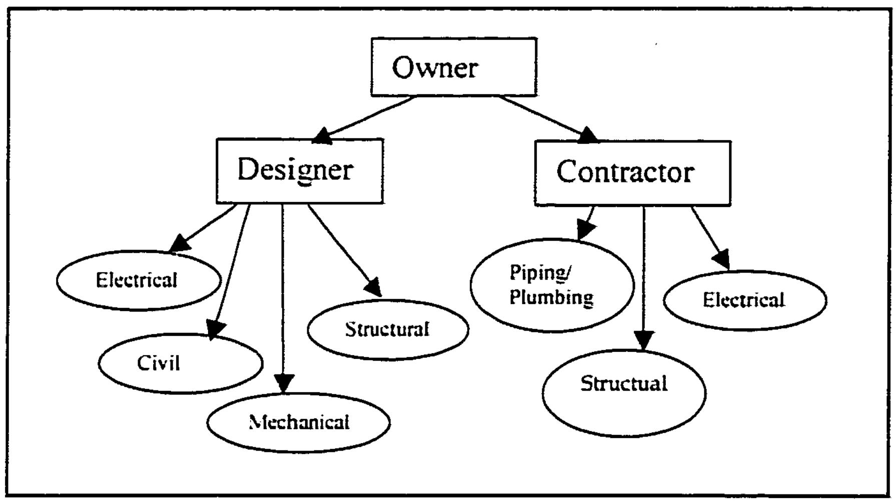

Figure 2.2 Design-Bid-Build

This contracting strategy is called Design-Bid-Build and is characterized by three phases: Design phase, Construction Bidding, and Construction phase. However, an alternative contracting strategy, Design-Build, is growing in popularity (Tulacz, 2000; Dyer-Smith and Tanahey, 2000; Yates, 1995). Design build eliminates the construction bidding stage, and encourages construction to integrate with design and vice versa. There are several contracting strategies in this category, but there is always one firm or joint-venture that is responsible to the owner. If different firms perform the design and construction, there are at least three contracting strategies that could be used. First, the construction firm could lead the project, and subcontract the design. Second, the design firm could lead the project and subcontract the construction. Third, the design and construction firms could form a joint venture to share the project risk and consolidate management and financing. Regardless of the contracting structure, design-build projects account for 34% of total construction awards in the last 15 years (Dyer-Smith and Tanahey, 2000), and this is a growing trend.

Design-build construction changes the focus of the design from a purely owner oriented design, to a construction oriented one. The design firm will sometimes have a stake in the construction phase, and it is then in their financial best interest to develop a construction friendly design. Designers should evaluate what construction personnel need from a design, since this will increase the value of their design. The methodology presented in this dissertation will help in this evaluation process.

2.3.2 A Diverse and Variable Market

In the marketplace, the only constant is change. As populations shift and grow, industries emerge, thrive and expire; governmental policy and economics influence every sector of the civil engineering industry. Methods of doing business also shift. For example, in the process and power industries, cost plus contracts were popular 30 years ago, whereas today turnkey, lump sum contracts are more common (Allen, 1998).

Understanding the market helps engineering firms formulate and maintain a competitive advantage, by offering services that are in demand, and setting themselves apart from the competition. The Journal of Management in Engineering conducted a survey in the summer of 1997. Eighteen percent of the 1997 Engineering News Record's top 500 firms responded to the survey, and the results are presented by the Professional Services Management Association (PSMA), the Advanced Management Institute of Architecture and Engineering, and the Professional Development Resources. (Marines and Rose, 1998) The results of this survey provide us with a general understanding of the current engineering firms and their understanding of the market demand.

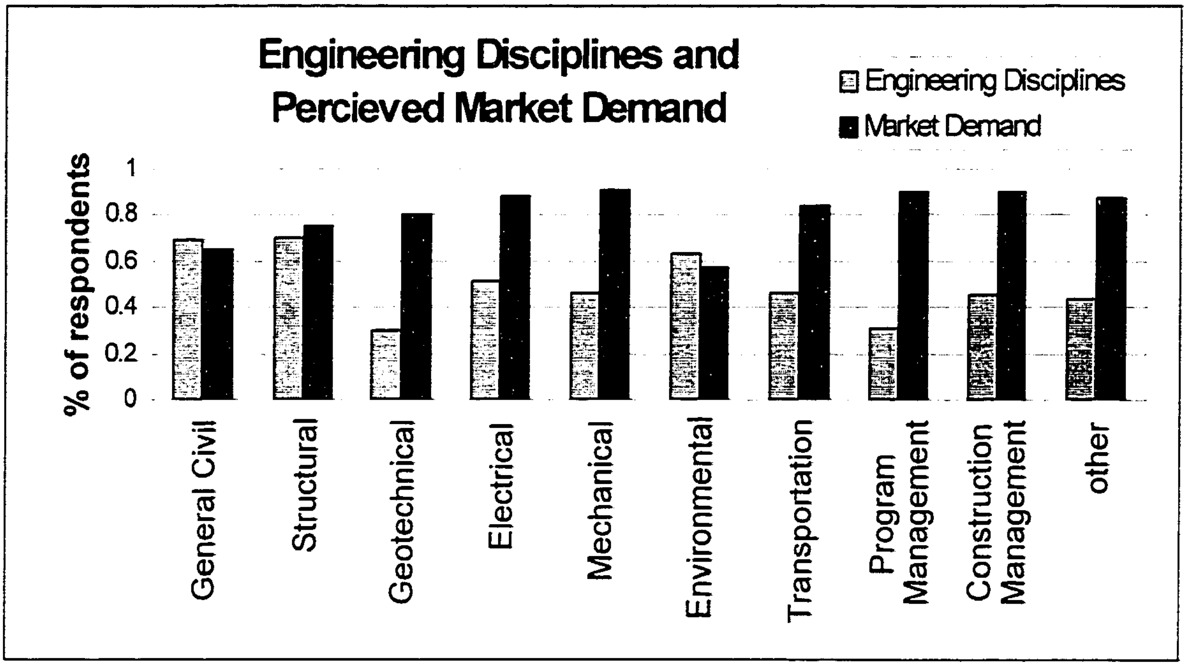

Figure 2.3 Current Engineering Services and Engineering Firm's Perception of the Current Demand for These Services (Allen, 1998)

Figure 2.3 shows the percent of respondents who offer these engineering disciplines (the first bar), and the second bar in each set represents the market demand as it is perceived by the engineering design firms who answered the survey. This figure juxtaposes the survey respondent's engineering services with their perception of market demand for these same services. The market demand is below the supply for general civil engineering services, but for specialized design services, the perceived market demand is higher than the supply. The laws of economics dictate that the suppliers (e.g., engineering designers) can charge a premium for the services that are in high demand, but the services where supply outweighs demand are unprofitably competitive. (Nagle and Holden, 1995)

The survey respondent's clients range from private industrial owners to local state and federal governments. They perceive a growing demand for foreign government work as third world countries invest in their infrastructure.

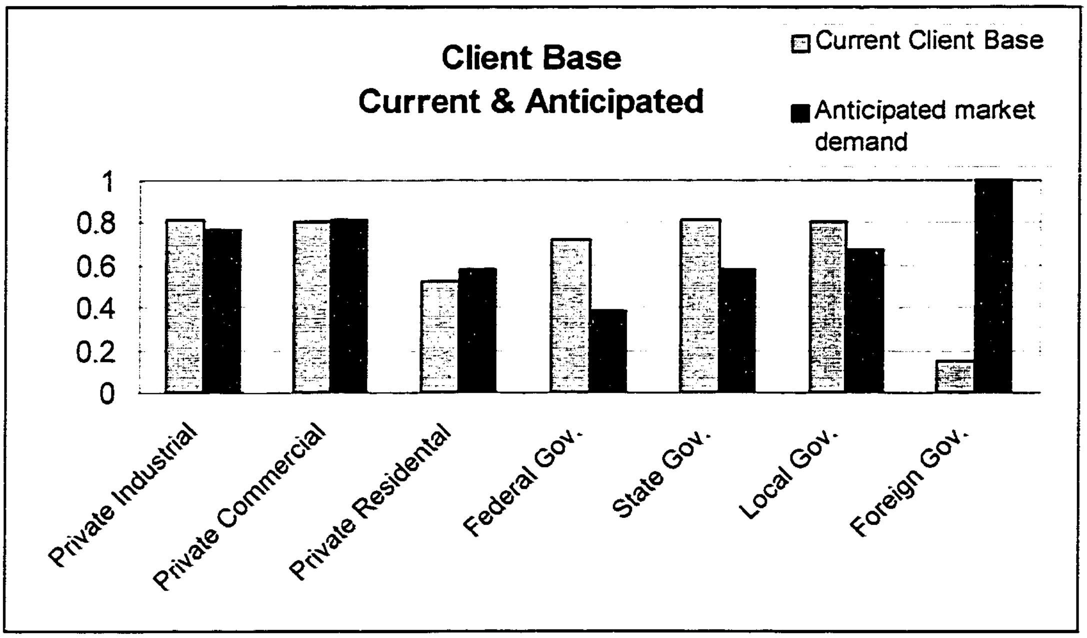

Figure 2.4 Present and Anticipated Client Base

Traditional engineering design services are becoming unprofitably competitive. (Moscovitch, 1996) Project services, traditionally outside of the designer's scope, are being picked up by design firms to make their services more attractive. (Tulacz, 2000)

Design firms are adding services to their offering to gain a competitive advantage and create profitable project conception, design and construction packages. Project support services include: at risk construction, facility operation, equity financing, and general contracting.

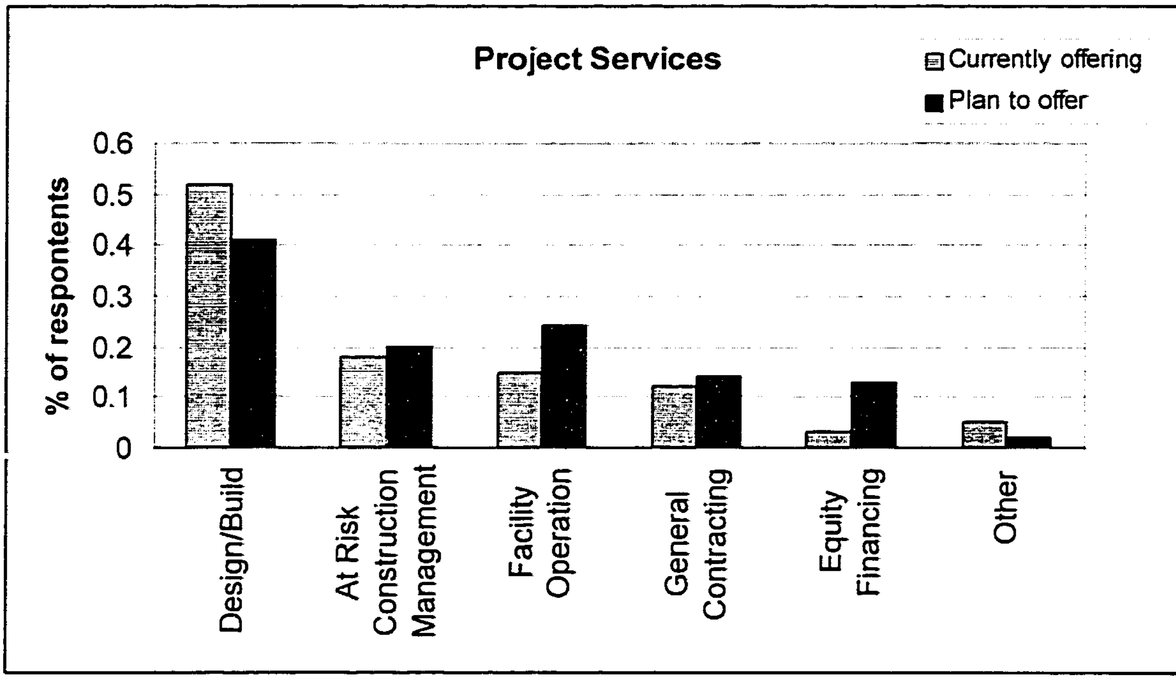

Figure 2.5 Project Services Outside of Traditional Design Services (Allen, 1998)

An engineering company that will also assist the owner with project development, financing, and construction management services, is potentially more attractive to a perspective client, and as shown in Figure 2.5, project services beyond engineering design is a growing trend.

As the PSMA study shows, the marketplace is very diverse in engineering expertise, types of project delivery services, as well as contracting strategies. There are a variety of owners with different backgrounds, financing requirements and goals. Consequently, it is important for engineers to assess the market for engineering services, as well as the contractual, product and service trends in the marketplace. There are many research tools in the field of Marketing Research that assist businesses in this type of market investigation. Marines and Rose report a growing awareness and utilization of marketing techniques by engineering designers in the PSMA study. (Marines and Rose, 1998)

Others have encouraged engineers to pursue marketing as an important component of the engineering design firm:

> "A plan based on thorough market research allows an engineering firm to anticipate and take full advantage of new business opportunities as they arrive… The buying process in most industries is generally based more on emotional than on technical factors. Often decision makers buying engineering services are looking at several firms that appear to have the same qualifications. Successful marketing professional convince their clients and prospective clients that they understand their clients' problems and that their firm is the most qualified to provide solutions." (Smallowitz and Molyneux, 1987)

This dissertation presents models that incorporate marketing research with engineering proposal development. One objective is to translate owners' perception of value in the design service industry into a price for engineering service. A second goal is to develop a methodology whereby the engineer can assess the aspects or services that owner's value and develop this knowledge into winning proposals. Though this dissertation focuses on design services, the models developed herein may be applicable to any competitive bidding or competitive proposal market. This methodology is particularly useful in cases where price is not the only consideration in the selection process.

2.3.3 Selection Criteria for Design Services

As discussed in Chapter 1. the Brooks Bill stipulates that federal agencies cannot issue competitive bids for architectural. engineering or other professional services. The proposals may include price quotations. but selections should be based on value. According to the FAR 2.101. value based means "an expected outcome of an acquisition that. in the Government's estimation. provides the greatest overall benefit in response to the requirement."

Many state and local governments have laws. ordinances and regulations along these same lines. Therefore. it is generally unlawful to select a design firm based on fee alone for public sector contracts. In order to develop a competitive bidding model for design services. there is a need for a methodology to maximize the value-based proposal.

There has been extensive debate over bidding for design services. It is evident from the literature that fee-based selection is a common and potentially growing trend (Frey. 1999; Hatheway. 1995; Trigueros. 1995: Hatheway. 1996; Parks and McBride. 1987). Many argue that fee-based selection limits the quality of work and hurts the industry in general. They argue that selections should be based on qualification; a low design fee can be detrimental for overall project quality and constructability. and tend to increase costs in the construction phase. (Robison 1983) However. many are adding price to their qualifications lists. and many engineers feel that clients place too much weight on price in the selection process (Trigueros. 1995; Hatheway. 1996). Unlike pure fee-based competitive bidding, bidding for engineering services involves a combination of quality, expertise, reputation, as well as competitive pricing.

Quality based selection is a growing trend throughout the civil engineering industry, as evidenced by Florida DOT's move toward mid-bid or average bid selection methods. (Low Bid, 1998) They hope to improve quality and reduce litigation by relaxing the lowest bid requirement for obtaining construction work.

There is a shift in the procurement philosophy of public agencies. Though competitive bidding may be illegal for design services, public agencies need to justify costs and maintain a fixed budget. To maximize the value of the sercies, some agencies are developing new contracting strategies. For instance, for the new Sagadoahoc Bridge due to open to traffic in October, 2000, the Maine Department of Transportation solicited proposals for the bridge design. The selection committee of 19 people rated each proposal with a technical score. The lump sum price was then divided by technical score to obtain a price per technical point. In this way they defined the most valuable bid, or the proposal that offered the most per design dollar. (Phipps, 2000)

The other side of this illustration was that the winning firm left $15.7 million on the table. In other words, the winning team could have increased their bid by $15.7 and still won the contract. They had a very high technical score, and comparatively low price. The methodology developed in this dissertation is aimed at these types of problems:

1. How to define the factors that the owner deems most valuable

2. How to give a dollar value to these factors to estimate an optimal winning bid and minimize the money left on the table.

2.3.4 Changing Demand

Michael J. Piore, a professor at MIT, sums up the recent history of the US economy:

> "Until the 1970's, traditional American business structures seemed to work well. The American Business system, based on a long-standing and stable economic underpinning, was characterized by low, stable energy prices, fixed currency exchange rates and government regulations. The static environment encouraged the entrenchment of specialization, vertical integration and divisions of labor in the corporate world... Today, markets place a heavy premium on variety and delivery speed..." (Russell and Flack, 1998)

Design firms face increased competition and complexity in the marketplace (Kogan, 1995; Smallowitz and Molyneux, 1987), and client ownership structures have become more complicated (Shuman, 1992) For example, as illustrated by the PSMA study presented in section 2.3.2, (Maries and Rose, 1998) the industry is consolidating to provide project life-cycle support services, e.g., design-build, finance-design.

To meet the variety of demand, engineering design firms vary in size and scope. Firm sizes and expertise vary from independent, specialized, single-person design offices to international, multifunctional, tens of thousand-person firms. Firms have also created partnerships and joint ventures to share risk and bid as a team, but the distinction between designer and constructor remains clear. Rarely will a design engineer manage construction, or a construction manager design a project. Though there are many specialized engineering design firms, we can categorize all engineering firms as one of three types (Stasiowski, 1993):

1. Traditional design firm. These firms are focused on good engineering practice. They emphasize quality and reliability. They are slow to adopt new technology, and are generally not forward thinking. These firms price to compete with other traditional firms, and once a price is set, they must manage their projects carefully to stay within the budget and make a profit. Firms in this category may not survive.

2. Service based design firm. These firms focus on client's needs. They will react to the market and serve exactly what clients ask for. However, these firms are also not always forward thinking in that they do not anticipate the needs of the market, but, rather, react to changes in client expectations. These firms price in accordance with owner expectation, and they must also meticulously manage their projects to secure a profit.

3. Industry leaders. This group of engineering companies leads the marketplace in technological innovation. They add new types of services, such as three-dimensional computer modeling and web- based project sites. Since there is no

precedent for new services, these firms also are price setters. They establish prices for front-end work that saves on construction costs, and therefore is valuable to the owner. Quality and service are expected across the industry, and these firms set themselves apart by innovating new types of project support services as well as design. With each technological innovation there are associated costs, and all projects must be managed, but new services allow designers to make a realistic profit and avoid the cost of competitive bidding.

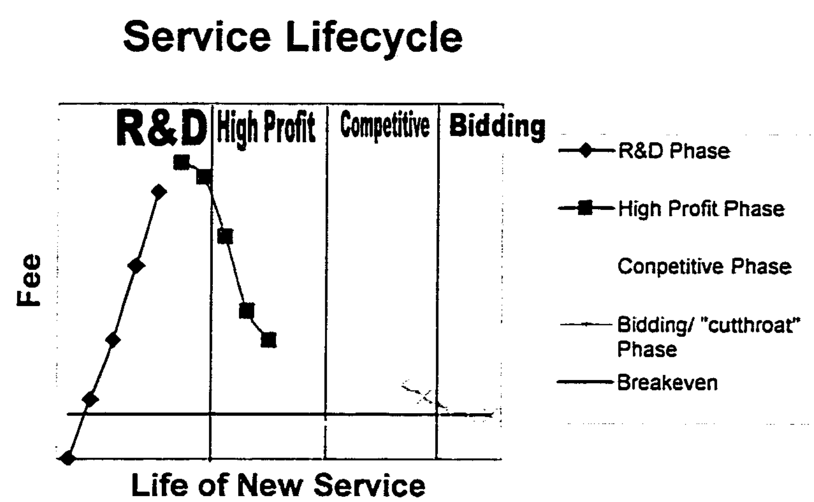

Figure 2.6 Life-Cycle Price Potential (Stasiowski, 1993)

When a product or service is new, the clients may have a fear of the unknown, and not be willing to pay for a product or service that is undocumented. Once established as an efficient and cost effective service, a client is willing to pay a higher price for the advantage of acquiring this service. Once the technology or methodology becomes an industry standard, the new service is no longer a competitive advantage and the fees begin to fall. The challenge then, is to capture what the future demand will be, and what prices to set. The models presented in this dissertation attempt to contribute to this end.

2.4 Need to Incorporate the Owner's Perspective

Research institutions, such as the Construction Industry Institute (CII), conduct studies in an attempt to formulate a picture of the industry and future markets. In the CII Research Report No. 30, Daniel Halpin and the CII research team report on the competition and future needs of international clients. (Halpin et al., 1993) The trends they identified include: customer focus, efficient resource utilization, flexible organization structures and management. They also report that design as well as construction firms are focusing more on marketing to understand customers and provide customized services.

Though marketing and industry studies of this type help shape an engineer's image of the owner's perspective. There has not been methodology established to incorporate other factors that influence the owner's selection process in a competitive proposal environment.

As illustrated in Chapter 3, the current bidding literature addresses the competitive selection process from a purely competitor or market-oriented approach. The theory presented in this dissertation attempts to incorporate the owner's perspective with competitive bidding theory, to formulate a model that accounts for factors arising from both the marketplace, other competitors, as well as the owner's needs and preferences.

The goals include:

1. Develop the winning proposal

2. Maximize owner's perceived value

3. Minimize the money left on the table

These will be addressed in Chapters 7, 8 and 9.

Reference

Allen, Richard K., (1998), "Professional Practice Survey Results", Journal of Management in Engineering, July/August 1998, pg.30-34.

American Society of Civil Engineers, ASCE, (2000), "ASCE Ethics", March 8, 2000, http://www.asce.org/aboutasce/ethics.html, 2000.

Bachner, John Philip, (1991) Practice Management for Design Professional: A Practical Guide to Avoiding Liability and Enhancing Profitability, John Wiley & Sons, Inc., New York, 1991.

Berzins, William E.,(1989) "Information Systems and the Economics of Engineering Services", Journal of Management in Engineering, Vol. 5, No. 1, January, 1989, pg. 32-41.

Computer Practices Committee (1976): (Charles F. Beck, Richard L. Land, Barry B. Flachsbart, Hugh McGrovy, Daniel Roos, David Schelling, Elias C. Tonias, Darryl W. Webber, Norman R. Greve (chairman)), " Computer Pricing Policy and Methods: Report of the Computer Practices Committee of the Technical Council on Computer Practices", ASCE Journal of Professional Activities, Vol. 102, No. E14, October, 1976, pg. 437-446.

Dyer-Smith, Howard, and Francis M Tanahey, (2000) "Designing Design-Build", The Military Engineer, Society of American Military Engineers, No. 603, January/February 2000, pg. 27-28.

"Engineering Could Become Just a Technical Degree, Conference Speakers Warn", (1995) Civil Engineering, ASCE, August 1995, pg. 10-14.

Fees '98, 1998 Fees Survey, Orinda, CA, Guidelines, 1998.

Frey, Robert S., (1999) Successful Proposal Strategies for Small Business: winning government, private sector, and international contracts, Second Edition, Artech House, Boston.1999.

Golish, M, McCunn, C. and Symonds, B., (1993), "The use of design automated software by government-contracted architect-engineer firms: a status report", Prep. 1R-FF-93/106, U.S. Army Construction Engineering Research Laboratories, Champaign, Ill.

Griffis, F.H. (Bud), and John V. Farr, (2000) Construction Planning for Engineers, McGraw Hill, New York, 2000.

Griffis, F.H. (Bud), and Carrie S. Sturts, (2000) Three-Dimensional Computer Models and the Fully Integrated and Automated Project Process of the Management of Construction, A Report on Best Practices, Construction Industry Institute, Research Report 152.

Griffis, F.H. (Bud), D. Hogan and W. Li, (1995) An Analysis of the Impacts of Using Three Dimensional Computer Models in the Management of Construction, Research Report 106-11, Construction Industry Institute, September 1995.

Halpin, D. W., Huang, R., Hastak, M., Dozzi, S. P., Unkefer, R. D. and Bopp, P. H., (1993) "The Future Needs of the Construction Industry's Worldwide Customers," A Report to the Construction Industry Institute, Austin, TX, March 1993.

Hampton, Delon, (1994), "Procurement Issues", Journal of Management in Engineering, November/December, 1994, pg. 45-49.

Harris, Donald (2000), Personal Interview, STV Group, New York office, October, 2000.

Hatheway, Allen W., (1996), "Corps Moves Closer to Bid Shopping", Civil Engineering, ASCE, June, 1996, pg. 35.

Hatheway, Allen W., (1995). "End the Evils of Bid Competition", Civil Engineering, ASCE, Nov. 1995, pg. 6.

Kogan, Raymond F., (1995) "Straight from the Source", Journal of Management in Engineering, March/April 1995, pg. 13-15.

"Low Bid Gives Way to Mid-Bid", Civil Engineering, 1998, pg. 10-11.

Marines, Louis L. and Stuart W. Rose, (1998) State of the Profession: Adaptation of the A/E Species: an investigation into the origins and phenomena affecting the futures of architecture and engineering firms in the 21st century, Professional Services Management Association, Advanced Management Institute, and the Professional Development Resources, Inc., Raleigh, NC, 1998.

"Moore's Law Will Continue to Drive Computing", PC Magazine Online, June 22, 1999 issue of PC Magazine. http://www.zdnet.com/pcmag/features/future/moore01.html

Moscovitch, Edward, (1996) "A Taxpayer's Look at a Sacred Cow: Public Sector Design in Massachusetts Two Decades After the Ward Commission", Civil Engineering Practice, Fall/Winter 1996, pg. 7-12.

Nagle, Thomas T., and Reed K. Holden, (1995) The Strategy and Tactics of Pricing: A Guide to Profitable Decision Making, Second Edition, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1995.

NCEES, (2000) The National Council of Examiners for Engineering and Surveying, http://www.ncees.org/, 2000.

O'Brien, W. (1998). "Capacity Costing Approaches for Construction Supply-Chain Management", Ph.D. Dissertation, Department of Civil and Environmental Engineering, Stanford University.

Parks, Gary A., and Robert R. McBride, (1987) "Competitive Bidding for Engineering Services", Journal of Professional Issues in Engineering, Vo. 113, No. 1, January 1987, pg. 66-76.

Peck, W.F., (1994), "Making the Most of Marketing," Journal of Management in Engineering, November/December, 1994, pg. 17-21.

Phair, M. and Mary B. Powers, (1998) "Processing Data", Engineering News Record, McGraw-Hill, August 31, 1998.

Phipps, Alan R., (2000) "Box Girder Balancing Act", Civil Engineering, ASCE, March 2000, pg. 33-39.

Potter, Kevin J., and Victor Sanvido, (1994) "Design/Build Prequalification System", Journal of Management in Engineering, March/April, 1994, pg. 48-56.

Robison, Rita, (1983) "Is There a Bid for Services in your Future?" Civil Engineering Magazine, ASCE, September, 1983.

Russell, Jeffrey S., and David A. Flack, (1998) "Seminar Review: Applying Technology in Project Management and Product Design", Journal of Management in Engineering, Sept./Oct. 1998, pg. 35-37.

Shuman, Chester A., (1992), "Managing for Profit", Civil Engineering, ASCE, November, 1992, pg. 72-73.

Smallowitz, Howard, and Deborah Molyneux, (1987) "Engineering a Marketing Plan", Civil Engineering, ASCE, Vol. 57, No. 8, August 1987, pg. 70-72.

Smith, Alan, P., (2000), Personal Interview, Parsons Corporation, Reading, PA office, November, 2000.

Stasiowski, Frank A., (1993) Value Pricing for the Design Firm, John Wiley & Sons, Inc., New York, 1993.

"The Summit on the Future of Engineering Software: Whitepaper", (1999) Cad Society Meeting, Chicago, Nov. 8, 1999, http://www.cadsociety.org/summit/whitepaper.htm

Tippett, Donald D., and Paul LaHoud (1999), "Managing Computer-Aided Civil Engineering Design Services", Journal of Management in Engineering, March/April, 1999, pg. 63-71.

Townsend, Alair A., (1988) Office of the Mayor, Office of Management and Budget, Standard Established Pursuant to Certificate of the Mayor for Financing Capital Projects: Design Services – Buildings, Major Structures and Park Facilities. The City of New York, December 20, 1988

Trigueros, Ruben, (1995), "Quality, Not Cost, Rescues Profession", Civil Engineering, ASCE, December, 1995, pg. 35.

Tulacz, Gary J., (2000) "Hot Markets Shift Into Higher Gear", Engineering News Record, April 10, 2000, pg. 56-64.

Veshosky, David, (1994) "Portfolio Approach to Strategic Management of A/E Firms", Journal of Management in Engineering, Sept./Oct. Issue, pg. 41-47.

Vest, David and David Crown, Personal Telephone Interview, CH2M Hill, November, 2000.

Widman, Sam (2000), Personal Interview, Ammann & Whitney New York office, December, 2000.

Yates, J.K., (1995) "Use of Design/Build in E/C Industry", Journal of Management in Engineering, Nov./Dec. 1995, pg. 33-3.

Chapter 3

Competitive Bidding Theory

"The important thing to remember is not this particular method, but the fact that the tools of operations research can successfully be applied in the area of competitive bidding."

-Lawrence Friedman, Operations Research Group, Case Institute of Technology, 1956

3.1 Introduction

There are two types of bidding situations that occur in the marketplace. (Friedman, 1955) The first is closed bidding. In this case, bidders submit one bid each and the judge(s) chooses the highest or lowest bid as dictated by the rules. Most bidding sessions in the civil engineering industry fall into the closed bidding category. The second bidding scenario is an auction or open bidding. In this situation, the bidders repeatedly submit bids in competition with other bidders to become the highest or lowest bidder. In the civil engineering literature, this would be referred to as bid shopping.

As it was noted in Chapters 1 and 2, competitive bidding for architectural and engineering design services is generally illegal for federal agencies and many public agencies on the state, city and local levels. The pivotal law, the Brooks Bill, enacted in 1972, mandates that contracts for architectural and engineering professional services be negotiated based on demonstrated competence and qualifications, at fair and reasonable prices. (Robinson, 1983) However, it is evident from the literature that price is a significant factor in the selection process. (Hatheway, 1996 and 1995, Trigueros, 1995, Parks and McBride 1987) As the Federal Acquisition Regulation (FAR) section 15.101 states: "In different types of acquisitions, the relative importance of cost or price may vary." (FAR, 2000) Industry professional lament that all too often too much emphasis is placed on lowest fee (Hatheway, 1995; 1996; Trigueros, 1995). Furthermore, the private sector is under no legal obligation not to bid shop or choose a design firm based on a quoted fee. Consequently, although existing competitive bidding models have limited applications for the procurement process of engineering design services, they have some relevance. Moreover, to make the competitive bidding models more applicable, there is a need to incorporate factors other than price into the competitive bidding methodology. The models presented in this dissertation attempt to do just that.

The procurement of architectural and engineering design services is generally still a competitive one (Friedlander, 1998), and the design firms compete on factors such as expertise and client relations, as well as price. In the procurement process for engineering design services, the situation is no longer as straight forward as the closed bidding or open bidding scenarios. As opposed to the lowest bidder wins criterion, the selection of design services is a process in which the judge or judges attempt to select the proposal that presents the greatest value.

There are several fields of research associated with the definition and characteristics of value (Holbrook, 1999), and the discussion of what value is, and how value is perceived is outside the scope of this thesis. Value, as it is used in this discussion, is defined by the Federal Acquisition Regulation, section 2.101 as "Best Value: the expected outcome of an acquisition that, in the Government's estimation, provides the greatest overall benefit in response to the requirements." (FAR 2000) In other words, the judges in the selection of design services strive to choose the proposal that presents the most technical expertise and service in relation to the proposal price. We have developed the term Value-Bidding to refer to this type of selection process.

In this chapter, we present the history of competitive bidding theory as it has been developed for the civil engineering industry. Bidding models in the civil engineering literature have focused mainly on construction procurement practices. The majority of bids for construction services fall into the category of closed bidding, and the fundamental assumption of many of these models is that the lowest bid wins. Consequently, the objective of the competitive bidding models is to maximize the expected profit or contractor's utility, given that they will only win jobs in which they present the lowest bid.

Section 3.2 of this chapter presents the background literature for the competitive bidding theories, establishes the basic Friedman and Gates models, and discusses the development of these models since their introduction to the field of construction engineering. Section 3.3 includes a discussion of the calculations and assumptions behind the determination of the probability of winning over a known competitor. One of the major contributions of this dissertation is a new way to develop the probability of winning over a competitor. The models presented in this dissertation introduce a significantly different approach to developing probability distributions for the likelihood of winning a contract in a competitive proposal situation. In Section 3.4, the computations for average bidder and unknown bidder are described in anticipation of the discussion and methodology presented in Chapter 6 of this thesis.

3.2 Mathematical Competitive Bidding Models: Literature Review

Bidding strategy models can be categorized into three general areas:

1. Probability models, (e.g., Friedman, 1956; Gates, 1967)
2. Decision-support systems (e.g., Ahmad and Minkarah, 1987)
3. Artificial Intelligence techniques (e.g., Christodoulou, 1998)

The first category is the oldest methodology type. These models are based on probability rules and the estimation of random variables. This section discusses the state of the art of the well-established and heavily debated probability-based competitive bidding models.

The second and third categories have been instigated by the computational abilities of computers. Decision-support systems process large amounts of data and weight factors leading up to a decision. For example, Ahmad and Minkarah, 1987, used utility theory to incorporate factors such as risk and other project uncertainties into their optimal bid markup calculations. Artificial intelligence programs use deductive reasoning with rules and sequential processing, as well as pattern recognition, generalization, and predictions based on historical data. These theories and models do not replace probability theory. They add to the analytical choices to address competitive bidding problems and provide methodologies for problems that lack the historical data necessary for probability theory solutions. (Fayek, 1998; Nguyen, 1985)

This dissertation adds to the volume of models based on probability theory. A new perspective is taken whereby the probability of winning is calculated in a very different way from other models in this category. As discussed in the following sections, traditional probability-based competitive bidding models use data from past bids to generate histograms for frequent and known competitors as well as average competitors (Friedman, 1956; Gates, 1967). These histograms are used to estimate the probability of winning over each competitor. This thesis proposes using a comparatively new approach for determining the probability of winning, choice-based conjoint analysis, which was developed in the field of marketing research. The reasoning behind this choice will become evident in Chapters 4 and 5, which cover conjoint analysis and Value-Bidding respectively.

After the decision to bid has been made, the general problem that most competitive bidding models in the construction industry address can be stated as follows: Given the rule that the lowest bid wins, what is the probability of winning the contract if there are a given number, n, competitive bids submitted in competition for a contract? (Rosenshine, 1972) In general, the estimation of the probability of winning is based on two assumptions. First, it is assumed that there is a constant relationship between competitors' bids and the contractor's estimates of direct costs. Second, it is assumed that the competition will act in the future as they have acted in the past. (Monroe, 1990)

Many of the competitive bidding models have focused on the goal of maximizing the contractor's profits. But, there are several different objectives that bidders might have when bidding for a job, and the relative importance of these objectives may vary from job to job. (Fayek, 1998) For example, a contractor might want to minimize losses and win a job for the sole purpose of keeping employees occupied. Or, a contractor might want to minimize a competitor's profits to maintain their own long-range competitive position (Gates, 1967). The numerous objectives that a bidder may have can be grouped into three common objectives:

1. To win the project
2. To enter a new geographical or technical area
3. To maximize the project's contribution to profit

The first two objectives are discussed in Chapter 7, and the third in Chapter 8 of this dissertation.

The state of the art for probability-based competitive bidding models is presented by Bud Griffis in his 1992 paper:

1) A histogram can be developed to describe the ratio of a competitor's bid to our contractor's cost estimate

2) A function that represents the probability of winning can be estimated by integrating the histogram developed in step one.

3) One can determine the contractor's expected profit function by multiplying the probability-of-winning function by the ratio of competitor's bid to contractor's cost estimate minus one.

4) If there is more than one competitor, the probability-of-winning function can be estimated using the models presented by Friedman (1956), Gates (1967) and Benjamin (1972).

5) If there does not exist enough information to develop an individual histogram for a competitor, Friedman suggests a method by which one can develop a probability-of-winning function for an average bidder. (Griffis, 1992)

In the next few sections, the author introduces the Friedman and Gates models and introduces these models as the foundation for the theoretical development in this thesis.

3.2.1 The Friedman Model

Lawrence Friedman was the first to introduce a competitive bidding strategy to the operations research literature in 1956. (Christodoulou, 1998) The Friedman model assumes that the company's sole objective is to maximize the total expected profit.

(Friedman, 1956) Given this assumption, Friedman developed the following equation for the expected profit:

(3.1) $$E(x) = P(x)(x - C')$$

where P(x) is the probability of winning, x is the bid amount, and C' is the estimated cost corrected for bias.

(3.2) $$C' = e_1 \int_0^{\infty} S * h(S)dS$$

where e_1 represents the estimated cost of fulfilling the contract, S is the ratio of the true cost to the estimated cost, and h(S)dS is the probability that this ratio is between the values S and S+dS. Thus, Friedman's model accounts for the potential error in the cost estimation.

This set of equations, which defines expected profit, assumes that the cost of submitting a proposal and losing is zero. (Benjamin and Meador, 1979) Friedman suggests the user calculate and plot the expected profit curve to determine the bid that maximizes the profit. This curve takes on the general shape:

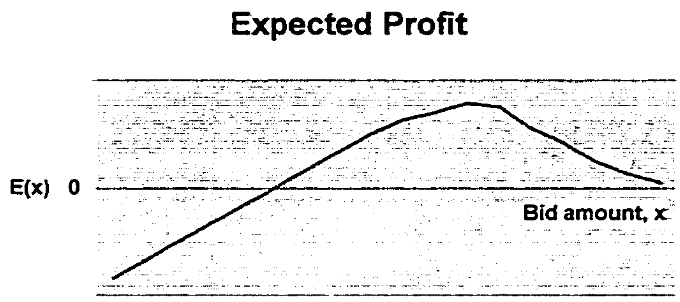

Figure 3.1 Plot of Expected Profit from Friedman's Bidding Model

In the Friedman model, it is assumed that each competitor's bid is chosen from a fixed distribution independent of the attractiveness of the contract. Therefore, this model neglects any factors relating to the type of job and the competitor's desire to obtain the contract. It seems logical that competitors would bid more competitively for an attractive contract then they would for an average job. However, Friedman's model assumes that the probability distributions for competitors' bids are fixed across all jobs. This simplifying assumption could be justified by the fact that the large variations in the cost estimates outweigh any subtle variations in the markups due to a competitor's interest in obtaining a particular contract. (King and Mercer, 1985) Others have gone on to develop more general models, i.e., Carr, 1982, who assumes variations in bids are basically due to variations in costs.

In his 1956 paper, Friedman acknowledges that the difficulty of calculating the expected profit is in determining the probability of winning. Friedman assumes that the probability of winning over a given competitor is independent from the probability of winning over a second competitor. Consequently, the joint probability of winning over all competitors of a given set is equal to the product of all of the individual probabilities. Given n competitors, the probability of winning with bid, b_0 is (Benjamin and Meador, 1979):

$$(3.3)\quad P[(b_o < b_1) \cap \ldots \cap (b_o < b_{n-1})] = P[b_o < b_1]P[b_o < b_2]\ldots P[b_o < b_{n-1}] = \prod_{i=1}^{n-1} P[b_o < b_i]$$

where,

P[] : probability of [event]

b_0 : bid of the contractor using the model

b_i : bid of the competitors

n : number of bids submitted in competition for the contract

Friedman recommends practitioners develop the probability of winning against known competitors using historical bidding data. This is based on the assumption that all bidders will behave in the future as they have in the past. From the announced contract awards, bidding patterns can be determined.

In the Friedman model, the competitors' bids, b_i, are weighted by the contractor's estimated cost, e_0. The ratio of the bid over estimated cost is often referred to as r_i in the literature.

$$(3.4)\qquad r_i = \frac{b_i}{e_0}$$

The estimated cost, e_0 is a random variable, and the bid amounts are stochastic. Consequently, the ratio of bid to estimated cost is a random variable whose outcome is defined by a probability distribution. Using data from bid histories, one can develop these distributions as functions of r_i. Typically, distributions look like those in figure 3.2.

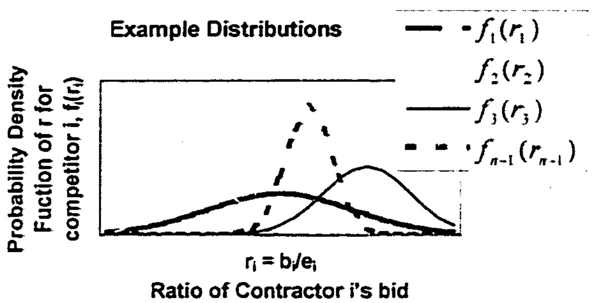

Figure 3.2 Example Probability Density Functions for Competitors' Bids

Having calculated the distributions of each competitor's bid standardized by the cost estimate, e_0, the probability of winning can be obtained:

$$(3.5) \qquad P(b_0 wins) = \int_{r_0}^{\infty} f_1(r_1)dr_1 \int_{r_0}^{\infty} f_2(r_2)dr_2 \cdots \int_{r_0}^{\infty} f_{n-1}(r_{n-1})dr_{n-1}$$

Equation (3.5) is only valid if the competitors' bids are mutually independent random variables.

However, Matthew Rosenshine points out in his 1972 paper, that Friedman's model is not limited to the case where the bids are independent. If $r_1, r_2, \ldots r_{n-1}$, are not mutually independent, then the historical data should be used to develop a joint probability density function of the random variables $r_1, r_2, \ldots r_{n-1}$. And, consequently, the probability of winning with a bid, b_0, would be:

(3.6) $$P(b_0\, wins) = \int_{r_0}^{\infty}\int_{r_0}^{\infty}\ldots\int_{r_0}^{\infty} f(r_1, r_2, \ldots r_{n-1})\,dr_1\,dr_2 \ldots dr_{n-1}$$

where $f(r_1, r_2, \ldots r_{n-1})$ is the joint probability distribution of the bid to cost estimate ratios for all correlated competitors. Methodologies for determining the probabilities of winning will be discussed further in section 3.3.

Friedman also introduces the model of an average bidder. If bidders are not known, the probability distribution of their bids can not be known. It is then necessary to develop a probability distribution for unknown bidders. This is discussed in section 3.3.2.

3.2.2 The Gates Model

In 1967, Gates adopted Friedman's underlying assumption that bidders want to maximize their expected profit. He defines the expected profit, EV, to be the probability of winning, (p), times the estimated value of profit, P. EV = (p) P. In his 1967 paper, Gates progresses through a number of different scenarios: Lone-Bidder, Two-Bidder, Many-Bidder, All-Bidders-Known, Number-of-Bidders-Known, Least-Spread, and Unbalanced bidding strategies. In each case, he defines the probability of winning, (p) and it's relationship to the estimated profit, P. Just as Friedman suggests, Gates accumulates data regarding past bids of competitors, and develops probability-of-winning functions for each bidder. Gates' theory differs however, in his method of combining the individual probabilities of winning over each competitor. Gates first proposed that the probability of beating n-1 known competitors is:

$$(3.7)\quad P[(b_0 < b_1) \cap (b_0 < b_2) \cap \ldots \cap (b_0 < b_{n-1})] = \frac{1}{1 + \frac{1 - P(b_0 < b_1)}{P(b_0 < b_1)} + \ldots + \frac{1 - P(b_0 < b_{n-1})}{P(b_0 < b_{n-1})}}$$

or

$$(3.8)\quad P(b_0 wins) = \frac{1}{1 + \sum_{i=1}^{n} \frac{1 - P(b_0 < b_i)}{P(b_0 < b_i)}}$$

Gates' equation can be derived using the laws of probability (Rosenshine, 1972). Given the following equations for the probability of the contractors bid winning over the ith competitor:

$$(3.9)\quad P(b_0 < b_i) = \int_{r_0}^{\infty}\int_{0}^{\infty} f_i(r_0, r_1) dr_0 dr_i \qquad i = 1,2,\ldots,n-1$$

or

$$P(b_0 < b_i) = \int_{0}^{\infty} f_0(r_0) dr_0 \int_{r_0}^{\infty} f_i(r_i) dr_i \qquad i = 1,2,\ldots,n=1$$

if r_0 and r_i are independent.

Rosenshine (1976) begins his derivation with the following equation. It is a basic postulate of probability theory that given events in a sample state space, S, the sum of the likelihood of these events should equal 1.

(3.10) $$P(A) + P(B) + P(C) + \ldots P(Z) = 1, \quad S \in \{A, B, \ldots Z\}$$

where events A, B, C through Z make up a complete sample space. If we define a closed bid as the sample space, S, the events, A,B, C..., could represent the events of each bidder winning. Events A,B, C and so forth, are mutually exclusive and collectively exhaustive.

(3.11) $$P(b_o \text{ wins}) + P(b_1 \text{ wins}) + P(b_2 \text{ wins}) + \ldots + P(b_{n-1} \text{ wins}) = 1$$

Second, the Multiplication Rule of Probabilities states that the intersection of two events, A and B, should be equal to the conditional probability of A given B times the probability of B. Rearranging this equation we can get:

(3.12) $$P(A \mid B) = \frac{P(A \cap B)}{P(B)}$$

Rosenshine defines events A and B as the events that the contractor wins over competitor i, $b_0 < b_i$, and that either the contractor or competitor i win the bid, $\text{b}_0 \text{ or b}_i \text{ wins}$, respectively. Consequently, we obtain the following equation:

(3.13a) $$P(b_0 < b_i \mid \text{b}_0 \text{ or b}_i \text{ wins}) = \frac{\text{P}(b_0 < b_i \cap \text{b}_0 \text{ or b}_i \text{ wins})}{P(\text{b}_0 \text{ or b}_i \text{ wins})}$$

The intersection of the events $b_0 < b_i$ and b_0 or b_i wins is simply that b_0 wins. Therefore, for i = 1, 2,...n-1, we have

(3.13b) $$P(b_0 < b_i \mid b_0 \text{ or } b_i \text{ wins}) = \frac{P(b_0 \text{ wins})}{P(b_0 \text{ or } b_i \text{ wins})}$$

It can also be argued that the events b_0 wins and b_i wins are mutually exclusive. Therefore, the probability that b_0 or b_i wins equals the probability that b_0 wins plus the probability that b_i wins: $P(b_0 \text{ or } b_i \text{ wins}) = P(b_0 \text{ wins}) + P(b_i \text{ wins})$.

Solving equation 3.13b for $P(b_i$ wins) Rosenshine gets:

(3.14) $$P(b_i \text{ wins}) = \frac{P(b_0 \text{ wins})[1 - P(b_0 < b_i \mid b_0 \text{ or } b_i \text{ wins})]}{P(b_0 < b_i \mid b_0 \text{ or } b_i \text{ wins})}$$

If we substitute this equation into equation 3.11. for all possible b_is. Rosensine derives the following:

(3.15) $$P(b_0 \text{ wins}) + \frac{P(b_0 \text{ wins})[1 - P(b_0 < b_1 \mid b_0 \text{ or } b_1 \text{ wins})]}{P(b_0 < b_1 \mid b_0 \text{ or } b_1 \text{ wins})} + \ldots$$

$$+ \frac{P(b_0 \text{ wins})[1 - P(b_0 < b_{n-1} \mid b_0 \text{ or } b_{n-1} \text{ wins})]}{P(b_0 < b_{n-1} \mid b_0 \text{ or } b_{n-1} \text{ wins})} = 1$$

Solving this equation for $P(b_0$ wins) Rosenshine obtains the following:

(3.16)

$$P(b_0 \text{ wins}) = \frac{1}{1 + \frac{[1 - P(b_0 < b_1 \mid b_0 \text{ or } b_1 \text{ wins})]}{P(b_0 < b_1 \mid b_0 \text{ or } b_1 \text{ wins})} + \ldots + \frac{[1 - P(b_0 < b_{n-1} \mid b_0 \text{ or } b_{n-1} \text{ wins})]}{P(b_0 < b_{n-1} \mid b_0 \text{ or } b_{n-1} \text{ wins})}}$$

Rosenshine presents this equation as equivalent to Gates'.

3.2.3 Comparison and Choice, Friedman or Gates

The two models, Friedman's and Gates', stimulated a long debate, and many researchers compared the models theoretically and empirically. (Benjamin, 1972; Benjamin and Meador, 1979; Rosenshine, 1972; and Dixie, 1974) The author has chosen to build upon the Gates model for reasons first argued by John Dixie in 1974. Dixie argues that the model to be used for the competitive bidding process must predict the likely consequences of each possible course of action. He proceeds to make a case with the following simple example: In the case where all n bidders have the same distribution of bids, then the probability of a particular bidder winning is $\frac{1}{n}$. In other words, each bidder has an equal chance of winning the bid. Similarly, the chance of the first bidder winning against only the second bidder is ½. If there are only two bidders, they have equal chance of winning the bid (given that they have equal distributions). If the probability of a contractor winning the bid against any single competitor is, ½, (i.e.,

$P(b_0 < b_1) = P(b_0 < b_2) = \ldots = P(b_0 < b_{n-1}) = \frac{1}{2}$, then Friedman's expression gives:

(3.17) $$P(b_o wins) = \prod_{i=1}^{n-1} P[b_o < b_i] = \prod_{i=1}^{n-1} \frac{1}{2} = \frac{1}{(2)^{n-1}} \neq \frac{1}{n}$$

Since Friedman's model does not estimate the known probability of winning in this case, it is not a good model to use for the following theoretical development.

The Gates model, on the other hand, predicts the expected answer in this example:

(3.18) $$P(b_0 wins) = \frac{1}{1 + \sum_{i=1}^{n-1} \frac{1 - P(b_0 < b_i)}{P(b_0 < b_i)}} = \frac{1}{1 + \sum_{i=1}^{n-1} \frac{1 - \frac{1}{2}}{\frac{1}{2}}} = \frac{1}{1 + \sum_{i=1}^{n-1} 1} = \frac{1}{n}$$

Furthermore, empirical studies show that when the Gates model is used, there is a closer correlation between the frequency of successful bids and the probability of winning, than when the Friedman model is used. (Gates, 1976; Benjamin and Meador, 1979)

3.3 State of the Art in the Determination of the Probability of Winning

3.3.1 Friedman's and Gates' Approaches

In their models, Friedman and Gates use continuous probability distributions to model the uncertainty in estimating the competitor's bids for any given future job. Recall that the competitors' bids are standardized by the contractor's cost estimate, and this ratio is designated as r_i: (equation (3.4) $r_i = \frac{b_i}{e_0}$). The distribution of this ratio for the ith competitor is notated as $f_i(r_i)$. Consequently, the estimation of the probability of winning over competitor i's bid can be expressed as equations 3.9 which are repeated here:

(3.19) $$P(b_0 < b_i) = \int_{r_0}^{\infty}\int_{0}^{\infty} f_i(r_0, r_1) dr_0 dr_i \qquad i = 1,2,\dots,n-1$$

or $$P(b_0 < b_i) = \int_{0}^{\infty} f_0(r_0) dr_0 \int_{r_0}^{\infty} f_i(r_i) dr_i \qquad i = 1,2,\dots,n=1$$

if r_0 and r_i are independent. (Rosenshine, 1972)

Researchers have found it to be very difficult to determine these distribution functions. In theory it is reasonable to estimate the distribution of competitor i's bid to cost ratio from historical bidding data; however, it has been found at times to be prohibitively difficult to amass enough data on a specific competitor to estimate a cumulative probability distribution. Furthermore, there is a question of the mathematical validity of a continuous distribution in that the data do not come from the same repeated experiment. Under classical statistical procedures, to develop a valid distribution it is necessary to collect data from the same repeatable experiment to assure that other factors are not confusing the true cause of the variation. (Benjamin, 1972) In fact, many researchers agree that there are other factors involved in the mark-up choice of competitors, (Christenson, 1965; Carr and Sandahl, 1978; Griffis, 1992; Christodoulou, 2000), and that these should be accounted for in the development of the probability of winning. This issue will be discussed in section 3.4.

3.3.2 Average and Unknown Bidders

At times, a designer or contractor has limited knowledge as to who might also be submitting a proposal or bid in competition with them. Up to this point, the author has addressed only the case where the competitors are known. There are many cases where the contractor may be unfamiliar with a competitor, and for this reason, researchers have developed models for average and unknown bidders.

Average competitors are the typical competitors, and can be modeled as the average of known competitors. Whereas, an unknown competitor or stranger is a wild card. For one reason or another, the designer or contractor may determine that one or more of the competitors are unknown. Either they are atypical for the industry, or they are newcomers.

Friedman presented the first of these models in 1956. He defines the average bidder as having a bid-to-cost ratio distribution that is calculated from the combination of all previous ratios on record. In other words, Friedman recommends the contractor incorporate all of the bid-to-cost ratio records they have collected into one histogram and derive a distribution function from this cumulative histogram. Since all of the bids are incorporated into one histogram, the resulting distribution function represents the average bid-to-cost ratio for all of the contractor's competitors. Just as with the single known competitor, a function, f(r), which is derived from the histogram, represents the average probability density function for all bidders the contractor has bid against. The probability of any bid, x being lower than a single average bidder can be expressed as:

$$\int_{x/C}^{\infty} f(r)dr \qquad (3.20)$$

where x is the bid amount, C is the estimated cost, and r is the ratio of the competitor's bid to the contractor's estimated cost.

If it is unknown how many bidders there might be, we can generalize the probability of winning by incorporating a probability distribution for the expected number of competitors based on the number of bidders in the past. Let, g(k), represent the probability there will be k bidders. The probability of winning can then be written as (Freidman, 1956):

$$P(x) = \sum_{k=0}^{\infty} g(k)\left[\int_{x/C}^{\infty} f(r)dr\right]^{k} \qquad (3.21)$$

Just as it was assumed for a single known competitor, the use of the average bidder distribution function derived in this way is only valid if we can assume that the competitors in the future will bid as competitors have in the past.

Gates presented a variation of this method in 1967. Gates suggests that the probability of winning over a typical competitor, p_t be developed from the histogram of all past typical competitor bids. Given any number of n typical competitors, the overall probability of winning could be calculated as:

(3.22) $$P(x) = \frac{1}{n\left[\frac{1-p_t}{p_t}\right]+1}$$

Both Friedman and Gates develop the probability of winning over a typical competitor based on the average of all recorded typical past bids. However, the distinction lies in the method they use to calculate the overall probability of winning given more than one competitor.

Others have also addressed the average bidder problem. For example, Casey and Shaffer (1964) introduce a geometric mean method for calculating the probability of winning over an average bidder.

(3.23) $$P(b_0 < b_a) = \sqrt[n]{\prod_{i=1}^{n}\left[1 - F_i\left(\frac{b_0}{c_0}\right)\right]}$$

where b_a is the average bid, b_o is the contractor's bid, F_i (b_o/c_o) is the cumulative distribution function of the ratio of contractor's bid, b_o to estimated cost, c_o, and n is the number of bidders.

Casey and Shaffer also incorporate a distribution for the case when the number of bidders is unknown. Given P(n=k) is the probability that the number of bidders equals any number k, they write the following probability of winning given an unknown number of average or typical bidders:

$$(3.24) \qquad P[(b_0 < b_1) \cap (b_0 < b_2) \cap ...] = \sum_{k=1}^{\infty} P(b_0 < b_a)^k \, P(n = k)$$

Where b_a is the bid for the average bidder defined above in equation (3.23).

Many have addressed the notion of average bidder and several suggest adjustments be made to account for current market conditions. (Kottas and Khumawala, 1973) For instance, Carr in 1987 presents an opportunity cost model for the competitive bidding problem. He introduces the LBC, the mean value of lowest opposing B/C ratio, and the MBC, the mean value of the B/C ratio against each expected opposing bidder. Carr also suggests that these estimates be adjusted for features of a project, changes in the market, or variations in the number of competitors. In this way, he incorporates the intuitive knowledge a contractor has of the market, the owner and the competitors. (Carr, 1987)

Some have found that competitor data leads to averaging over all competitors for a complete market overview. (King and Mercer, 1985). It was found that the variance between competitors was small and it was reasonable to suppose that the bids had a constant individual expected markup, which was the same for each competitor. Therefore, they grouped the bids together and treated them as the market against which the contractor bids.

Unknown competitors are more difficult to model. The very fact that they are strangers introduces a wild card into any possible prediction. Many suggest using the average bidder estimation when dealing with unknown competitors. (Friedman, 1956; Gates, 1967; Carr, 1987). However, others suggest subjective modification may be necessary to model an unknown competitor. (Kottas and Khumawala, 1973). However, there has been limited methodology presented for subjective modifications of this type. In general, for an unknown competitor, the uncertainty is greater, and therefore, the variance is larger for any stochastic variable. Though many models make no distinction, for this dissertation, the author deemed it valuable to distinguish between average and unknown bidders. The distinction is particularly relevant when modeling stochastic variables that influence the probability of winning. For instance, when modeling an average bidder, variances tend to be much smaller than when modeling unknown competitors. These ideas are fully developed in Chapter 6.

3.3.3 Comments and Other Developments Regarding the Probability of Winning

Some researchers have concluded that the efforts in determining continuous probability distributions for the bid to cost ratio for all competitors may be extraneous. Howard (1967) concludes and Benjamin (1972) confirms that it is "perhaps only necessary to determine the probability of beating the competitor who would otherwise be lowest bidder." For example, Broemser's model (Broemser, 1968) utilizes the mean and variance of the normal distribution of bid-to-cost ratio, r_l, with a variance of σ_ε^2. (Benjamin, 1972) Others have forgone the continuous probability distributions by using the more simplistic relative frequencies of winning over competitors, based on historical data. (Morin and Clough, 1969) However, most rely on the statistical data accumulated from past bidding sessions.

In the probability theory-based competitive bidding models, researchers have used historical bidding data to generate distribution functions for the likelihood of competitor's bids, and some have incorporated factors such as job risk, size, resource availability, etc., into a linear regression equation to find the distribution that defines the lowest bidder's likely bid (see section 3.4).

In this dissertation, the author extends the theory of probability estimation for competitive bidding models. This approach is taken for a number of reasons. First, the design procurement process has a number of factors that need to be accounted for in a bidding model. Second, there has not been a methodology presented that provides the users with a method to assess the subjective factors involved in a successful proposal.

3.4 Other Factors that Influence the Probability of Winning

Many have observed (King and Mercer, 1985; Whittaker, 1981; Carr and Sandahl, 1978; Fayek, 1998) that there are factors other than expected profit involved in a bidder's mark up decision (in a fee-based bidding scenario), and owner's selection (in a quality based bidding scenario). For instance, contracts vary in their attractiveness to bidders due to differences in project size and budget constraints, available resources, and job location (King and Mercer, 1985), and these factors vary across competitors for different jobs.

Linear regression has been used extensively to attempt to capture the effects and develop predictive models that incorporate factors such as job size, personal and professional risk, job duration, etc. For example, in 1968, Broemser introduced a model, which incorporates factors such as the estimated percent of cost not subcontracted, the estimated job duration, and the competitor's bid/estimated cost ratio:

(3.25) $$r_{l_j} = \sum_{k=0}^{\infty} \beta_k X_{jk}$$

where j indicates the jth job from which the observed dependent and independent variables are used to estimate the coefficients, β_k. The X_{jk}s represent the variables mentioned above (e.g., estimated percentage of cost not subcontracted, and estimated job duration). This model produces the normally distributed bid to cost ratio, r_l, with a variance of σ_ε^2. This distribution represents the lowest competitors bid, and can be used to estimate the probability of winning over the next lowest competitor. The probability of winning is then used to calculate the maximum expected profit.

Carr and Sandahl (1978) extend Broemser's work and verify their models using a small building contractor in Colorado. They present a model that estimates the low bid cost ratio (LBC) for any project and base their estimates on job factors such as number of competitors, cost of unskilled labor, and the total job cost. They utilize multiple linear regression to estimate the LBC:

$$LBC_{pred} = a + \sum_{j=1}^{k} \beta_j X_j \qquad (3.26)$$

where LBC_{pred} is the estimated value of the dependent variable LBC, 'a' is the sample estimator of the population constant, and k represents the number of factors incorporated into the model. The X_j are independent variables, e.g. ratio of the number of unknown to the number of total bidders, number of neighboring state competitors, and the cost of unskilled labor. As in Broemser's model, β_k represent the coefficients of regression and the 'a' is also a regression variable.

Researchers have tried to incorporate influence factors into competitive bidding models with increasingly sophisticated tools. The use of Fuzzy Logic to evaluate optimal bids was first presented in 1985 (Nguyen, 1985). Fuzzy sets are used to capture the qualitative and approximate terms involved in bid decision making, and they address the other factors, besides price, that affect a contractor's success in a winning project (Fayek, 1998). Of most interest for the purposes of this dissertation, is the situation when the contract is not awarded on the bases of lowest bid alone. Fuzzy set models take into account factors for construction contractors such as (Fayek, 1998):

1. Project characteristics, e.g., size
2. Design characteristics, e.g., contractor involvement in design process

3. Cost estimate characteristics, e.g. overhead vs. contract value
4. Project related risks, e.g. likelihood to unexpected climate
5. Project-related opportunities, e.g. innovation in design
6. Company characteristics, e.g., need for work
7. Corporate and budgetary, e.g., actual vs. budget turnover to date
8. Client, e.g., good contractor-client relationship
9. Competition, e.g., number of bidders, n
10. Characteristics of subcontractors and suppliers, e.g., flexibility to negotiate lower prices
11. Economic and political conditions, e.g., current unemployment rate.

Most of the competitive bidding models that take into consideration other factors beside price focus on factors that are either characteristics of the job, characteristics of the competition, or characteristics of the risk (e.g., Griffis, 1992; Fayek, 1998; Benjamin, 1972; Carr and Sandahl, 1978). Furthermore, the main focus has been on construction bidding scenarios, and there have been limited attempts to model the procurement process for design services. (Parks and McBride, 1987) There is a need to investigate factors that affect the owner's decision, primarily when price is only one factor involved in the selection process, and to incorporate these owner-based factors into a bidding model.

Many selection factors for design services are qualitative. The Federal Acquisition Regulation presents this list of selection criteria (FAR 26.602-1):

1. Professional qualifications for providing service
2. Specialized experience and technical competence
3. Capacity to accomplish work
4. Past performance
5. Location
6. Acceptability under other appropriate evaluation criteria

Many of these factors are subjective and the values are dependent on the owner's perceptions and interpretations. The models presented in this dissertation are designed to capture the subjective effects and incorporate the owner's perspective into the competitive procurement process for design services.

3.5 Conclusions

There are two limitations associated with the probability theory based bidding models. (Moselhi and Hegazy, 1992)

1) The formulation of a combined probability of winning over more than one competitor is debatable.
2) The state of the art does not account for qualitative factors that influence the bidding process, e.g., contractor's need for work, prevailing market conditions, and project-related risks.

The author addressed the first issue in section 3.2.3, i.e., the use of Gates' model is justified. This dissertation addresses the second limitation from a very different perspective: the owners' preference perspective. Other authors, (e.g., Broemser, 1968; Griffis, 1992), have incorporated work volume and project risks into their probability models; however, there has been limited pursuit of a model that addresses the Quality-based selection problem, and incorporates the influence of owners' preferences.

Furthermore, researchers and engineers make qualitative judgments and adjustments to bids in an attempt to reflect competitive advantages and disadvantages as well as market trends. (King and Mercer, 1985) Though much as been done in terms of addressing bid adjustments as the contractor is affected by the market conditions, i.e., volume-time function, (Griffis, 1992), the contractor's utility (King and Mercer, 1985; Ahmad and Minkarah, 1987) and opportunity costs (Carr, 1982), there has been little investigation into a methodology to quantify the adjustments to accurately reflect the clients' preference and value structures. Aminah Fayek, a professor with the University of Alberta, Edmonton identifies a need for a competitive bidding strategy that addresses the "consideration of other factors, besides price, that affect a contractor's chances of winning projects, since contracts are not always awarded to the lowest bidder. " (Fayek, 1998) This dissertation suggests a methodology of introducing client preference factors into the bidding decision models and addresses the competitive situation where proposals are chosen based on other factors as well as price.

References

Ahmad, I., and I. Minkarah, (1987) "An Additive Utility Model for Selecting Optimum Bid Price." Proceedings: 18th Annual Pittsburgh Conference on Modelling and Simulation. 18(1), pg. 367-373.

Benjamin, Neal B.H., (1972) "Competitive Bidding: The Probability of Winning", Journal of the Construction Division. ASCE, Vol. 98, No. ST9, September 1972, pg. 313-330.

Benjamin, Neal B.H., and Richard C. Meador (1979), "Comparison of Friedman and Gates Competitive Bidding Models", Journal of the Construction Division. Vol. 105, No. Co1, March 1979, pg. 25-41.

Broemser, Gary Milton, (1968) Competitive Bidding in the Construction Industry. Thesis (Ph.D.) Stanford University, 1968, in partial fulfillment of the degree of Doctor of Philosophy.

Carr, Robert I., (1987) "Competitive Bidding and Opportunity Costs." Journal of Construction Engineering and Management. ASCE Vol. 113, No. 1, March, 1987.

Carr, Robert I., (1982) "General Bidding Model." The Journal of the Construction Division. ASCE, Vol. 108, No. CO4, December, 1982, pg. 639-650.

Carr, Robert I. and John W. Sandahl, (1978) "Bidding Strategy Using Multiple Regression", Journal of the Construction Division. Vol. 104, No. CO1, March, 1978, pg. 15-26.

Casey, B.J., and L.R. Shaffer, (1964) "An Evaluation of Some Competitive Bid Strategy Models for Contractors." Civil Engineering Studies, Construction Research Series No. 4, University of Illinois, Urbana, IL, June, 1964.

Christenson, C., (1965), Strategic Aspects of Competitive Bidding for Corporate Securities. Division of Research, Harvard University, Boston, Mass. 1965.

Christodoulou, Symeon, (2000) "The Science in Human Intuition: Optimum Bid Markup Calculation in Competitive Bidding Environments Using Probabilistic Neural Networks", working paper.

Christodoulou, Symeon, (1998) "Optimum Bid Markup Calculation In Competitive Bidding Environments Using Fuzzy Artificial Neural Networks", Ph.D. Thesis, Columbia University, New York, New York.

Dixie, John M., (1974) "Bidding Models-The Final Resolution of a Controversy", Journal of the Construction Division. Vol. 100, No. Co3, September, 1974.

FAR, (2000) Secretary of Defense, Administrator of General Services and the Administrator, National Aeronautics and Space Administration. "Federal Acquisition Regulation," Published by GSA's FAR Secretariat on Behalf of DoD, GSA, and NASA, http://www.arnet.gov/far

Fayek, Aminah, (1998), "Competitive Bidding Strategy Model and Software System of Bid Preparation", Journal of Construction Engineering and management, January/February, 1998, pg. 1-10.

Friedlander, Mark C., (1998) "Design/Build Solutions", Journal of Management in Engineering, Nov./Dec. 1998, pg. 59-64.

Friedman, L., (1956) "A Competitive Bidding Strategy," Operations Research, Vol. 4, 1956, pg. 104-112.

Gates, Marvin, (1967) "Bidding Strategies and Probabilities", Journal of the Construction Division, ASCE Vol. 93, No. CO1, March, 1967, pg. 75-107.

Gates, Marvin, (1976) "Gates' Bidding Model – A Monte Carlo Experiment", Journal of the Construction Division, Vol. 102, No. CO4, Dec. 1976, pg. 669-679.

Griffis, F.H.(Bud), (1992) "Bidding Strategy: Winning Over Key Competitors", Journal of Construction Engineering and Management, ASCE, Vol. 118, No. 1, March, 1992, pg. 151-165.

Hatheway, Allen W., (1996), "Corps Moves Closer to Bid Shopping", Civil Engineering, ASCE, June, 1996, pg. 35.

Hatheway, Allen W., (1995), "End the Evils of Bid Competition", Civil Engineering, ASCE, Nov. 1995, pg. 6.

Holbrook, Morris B, ed., (1999) Consumer Value: A Framework for Analysis and Research, Routledge, London, England, 1999

Howard, R.A., (1967) "Value of Information Lotteries", IEEE Transactions on System Science and Cybernetics, Vol. SSC-3, June, 1967, pg. 54-60.

King, Malcom, and Alan Mercer, (1985), "Problems in Determining Bidding Strategies," The Journal of the Operations Research Society, Vol. 36, No. 10, Nov. 1985, pg. 915-923.

Kottas, John F., and Basheer M. Khumawala, (1973) "Contract Bid Development for the Small Business," Sloan Management Review, Spring, 1973, pg. 31-45.

Monroe, Kent M, (1990) Pricing: Making Profitable Decisions, 2nd edition, McGraw-Hill, Inc., New York, 1990.

Morin, T.L., and R. H. Clough, (1969), "OPBID: Competitive Bidding Strategy Model", Journal of the Construction Division, ASCE, Vol. 96, No. CO1, Proc. Paper 7308, June, 1969, pg. 93-97.

Moselhi, Osama, and Tarek Hegazy, (1992) "Discussion of Bidding Strategies: Winning Over Key Competitors by F. H. (Bud) Griffis," Journal of Construction Engineering and Management, Vol. 118, No. 12, December, 1992, pg. 656-658.

Nguyen, V.U. (1985) "Tender Evaluation by Fuzzy Sets" Journal of Construction Engineering and Management, ASCE, Vol. 111, no. 3, pg. 231-243.

Parks, Gary A., and Robert R. McBride, (1987) "Competitive Bidding for Engineering Services", Journal of Professional Issues in Engineering, Vo. 113, No. 1, January 1987, pg. 66-76.

Robison, Rita, (1983) "Is There a Bid for Services in Your Future?" Civil Engineering, ASCE, September, 1983, pg. 40-43.

Rosenshine, Matthew, (1972) "Bidding Models: Resolution of a Controversy", Journal of the Construction Division, Vol. 98, No. CO1, March 1972, pg. 143-148.

Rosenshine, Matthew, (1976), discussion of "Bidding Models: Truths and Comments" by Fuerst, M., Journal of the Construction Division, ASCE, Vol. 102, No. CO4, December, 1976, pg. 694-696.

Trigueros, Ruben, (1995), "Quality, Not Cost, Rescues Profession", Civil Engineering, ASCE, December, 1995, pg. 35.

Whittaker, J. (1981) "General Bidding Model," Journal of the Construction Division, ASCE, Vol. 108, pg. 639-650.

Chapter 4

Conjoint analysis

"In this sense, prescriptively as well as descriptively, consumer value shapes the design of marketing strategies"

-Morris B. Halbrook, A Framework for Analysis and Research, 1999

4.1 Introduction

Green and Roe. professors of marketing at the Wharton and Cornell University Schools of Business. first introduced the methodology of conjoint measurement to the marketing literature (Green and Rao. 1971). They acknowledge that the theoretical foundations date back to the 1920s. and that the 1964 seminal paper by a mathematical psychologist. Luce. and a statistician. Tukey. marks the beginnings of conjoint measurement as it is used today.

Green and Srinirasan coined the term Conjoint Analysis in their 1978 paper in the Journal of Consumer Research (Green and Srinirasan. 1978). Since that time. conjoint analysis has been a very popular method of measuring tradeoffs among multi-attributed products and services. It is presented in most marketing textbooks and handbooks as a common marketing research tool (Lehmann, et.al. 1998; Bagozzi, 1994, and Allison, et. al., 1992), and there is ongoing extensive academic research in this field (Gustafsson, Herrmann, and Huber, 2000).

Conjoint analysis has been enthusiastically embraced by industry. It is estimated that over 400 conjoint studies were conducted per year in the 1980's (Wittink and Cattin, 1989). Conjoint analysis has been used for new product development, concept evaluation, product repositioning, competitive analysis, product or service pricing, and market segmentation (Green and Srinivasan, 1990). The most famous commercial use of conjoint analysis, and possibly, the most complex to date, is the study conducted by the Marriott International, Inc., which resulted in the development of the hotel chain Courtyard by Marriott. (Wind, et.al., 1989). Researchers from the Wharton School of Business, Paul Green and Jerry Wind, along with Douglas Shifflet of D.K. Shifflet and Associates, and Marsha Scarbrough from Marriott successfully used conjoint analysis to design a new hotel. They used over 50 attributes of the hotel services, including room size and layout, lobby, bar and restaurant, gym and pool facilities, etc. Some details of this case will be examined later in section 4.2.

Using conjoint analysis, researchers attempt to capture consumer preferences and predict consumer choice. There are several methods, including rating, ranking and choice study techniques, but the underlying goal of most conjoint studies have been to determine the influence that various attributes of the product or service have on customer choice (Kress and Snyder, 1994). Important aspects of a product or service are identified, and variations are defined. There are three levels of detail in the product or service descriptions:

1. Alternative (or Profile). An alternative is a collection of attribute levels that defines a product or service.
2. Attribute. An aspect of a product or service.
3. Levels. The options within an attribute presented to consumers.

The first step in a conjoint study is the identification of important aspects of the product or service. These aspects are called attributes. For example, attributes of a hotel might include pool and gym facilities, square foot area for each room, bar and restaurant, etc. Levels are also identified for each attribute. For instance, 30, 45, 55 and 70 square feet might be the levels presented for the area of a hotel room. A collection of attributes, (one level per attribute), create an alternative or profile. These alternatives are then rated, ranked or compared in a customer survey in an attempt to capture consumer preferences.

Economists have defined the term utility as the measure of a person's preferences or judgments of preferability, worth, value and goodness (Fishburn, 1968). Given the customer's preference structure for alternatives, most conjoint techniques define partworths, (often referred to as utilities) for attributes and individual levels. (Green and Srinivasan, 1990). In conjoint analysis, if researchers assume an additive model, the utility of a product or service is the weighted sum of the object or service's preferable attribute levels (Green and Srinivasan, 1978). The basic assumption for most conjoint analysis is that the whole is equal to the sum of its parts.

In the process of consuming goods and services, there is a series of decisions that a buyer must make.

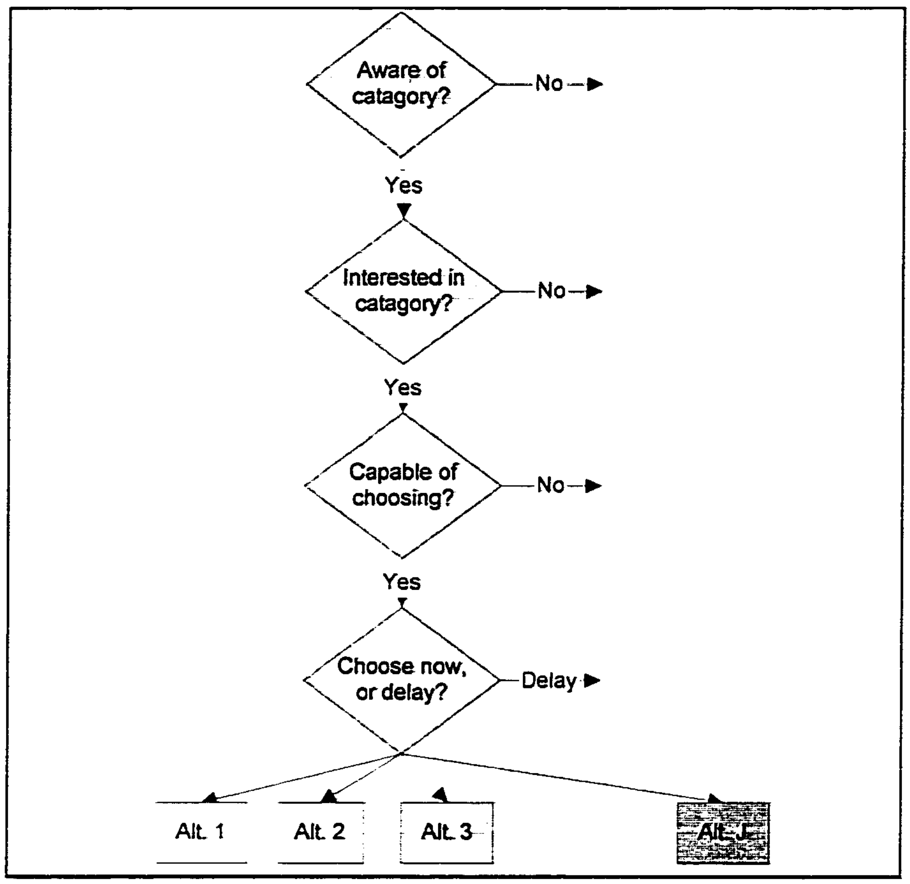

Figure 4.1 Decision Sequence of a Purchase Process (Adapted from Louviere et. al., 2000)

The abbreviation 'alt.' stands for alternative and refers to a set of attribute levels that represent the products or services provided. If the decision makers say no to any of these questions, the probability of the buyer acquiring the product or service is zero. This is a very generalized depiction of the consumer process, and Value-Bidding primarily addresses the last question, the prediction of consumer choice. However, it is interesting to note that there is a learning and decision process that supersedes the selection of any service. Specifically for engineering design services, this learning process includes an education about the types, levels, and quality of services that designers offer, and the owners' development of their objectives for the project. These preliminary decisions affect the expectations that an owner has when procuring design services.

As Louviere points out in his discussion of Figure 4.1, many applications of traditional conjoint analysis address the choice of brands or profiles, while other studies deal with concepts and general categories (Louviere, et. al. 2000). The brand decision is illustrated in the lower section of the diagram (choose now, or delay?); whereas the evaluation of concepts and categories resides further up the process, with the question, "Interested in Category?"

Generally, in the procurement of engineering services, the project type dictates the category of engineering services and type of engineering firm the buyer requires. However, it is the author's opinion that the education process whereby the owner learns about the engineering services required for their project(s) and the nature of those services, affects the final choices of engineering firms. This area has not been fully investigated and might prove to be an area for future research.

4.2 Conjoint Measurement: The Fundamental Assumptions

The fundamental assumption that governs most conjoint models is the assumption that the utility or the value of a project or service can be expressed as the sum of the utilities of the features or attributes of the project or service under study. (Lehmann, et. al., 1998). In other words:

4.1a $$\text{Utility for a product or service} = \sum_{\substack{\text{all} \\ \text{features}}} \begin{pmatrix} \text{Utility a feature} \\ \text{of the product or service} \end{pmatrix}$$

This is mathematically expressed as:

4.1b $$U(\alpha, \beta ... \zeta) = u(\alpha) + u(\beta) + ... + u(\zeta)$$

where the Greek letters α,β, to ζ represent the different attributes of the product or service. (levels progress from 1-A, 1–B, ... 1–Z, respectively), and the u() represents the utilities or part-worths for each attribute level.

Conjoint utilities are interval data and are scaled arbitrarily. Interval data is defined as:

> "Rating scales, common to marketing research, generates interval data, which are permitted the simple operations of addition and subtraction. Each interval is equal to the next interval. For example, it takes the same amount of heat to raise the temperature of water from 10 to 20 degrees as it does to raise it 20 to 30 degrees. However, interval data can not be expressed in ratios or multiples, i.e., 60 degrees to 30 degrees has no meaning, and 40 degrees is not twice as hot as 20 degrees." (Lapin, 1993)

There is a variety of insight researchers can gain from the utility and part-worths for products and services. For example, the part-worths provide a metric whereby the relative value of the attributes is demonstrated, (see section 9.3.3). Once the conjoint model is calibrated with the utility weights, a number of market simulation techniques can be used. Researchers have developed choice simulators that can approximate the probability of a product or service being chosen from a set of other products or services, and can estimate the likelihood of purchase.

Advantages of Traditional Conjoint Measurement over Self-explicit Approaches
More similarity to real choice in marketplace
High chance of obtaining real attribute weights
Less chance of receiving socially acceptable answers
Greater sensitivity
Greater chance of detecting non-linearities in partworth functions
Decreased likelihood of double counting
Advantages of Self-explicit Over Traditional Conjoint Measurement
Less cognitive strain on respondents
Limited simplifying-effects
Greater ease in data collection efforts
Easier data analysis and research design
Easier to handle large numbers of attributes
Faster data collection
Lower costs for data collection and analysis

Table 4.1 Advantages for Both Conjoint Measurement and Self-Explicit Approaches. Adapted from Table 1, Chapter 5, Gustafsson et al., 2000

There are many types of analytical methods that fall under the more general category of choice analysis (Louviere, et. al. 2000). In general, conjoint analysis refers to a set of models that determine consumer preferences and predict consumer choice, but these different theories often require different assumptions and analytical techniques. In their 2000 essay, the authors point out that, "Science seeks parsimonious and behaviorally meaningful models rather than complex statistical descriptions, which is why one must understand and appreciate model assumption." (Louviere et al., 2000).

There are four general categories of preference data collection methods and sources:

1. Ranking Alternatives. This was one of the first methods of application for conjoint studies (Green and Rao, 1971). Given a list of alternatives, the respondents rearrange the list to show the order of preference. Generally, the most preferred alternative is first, second preferred alternative second, and so on. Theoretically, if these alternatives were encountered in the market, the respondent would purchase the first alternative in their preference list. If the first alternative is unavailable, then they would buy the second, and so forth. In terms of the procurement of design services, this is analogous to a ranked short list, where the design firms are chosen based on their written proposals, and ranked in the order of preference. In the design procurement process, this ranking can change after more information is obtained through presentations, interviews or references.

2. Rating Alternatives. This is a metric scale that attempts to capture intention to buy or likelihood of purchase. This has the advantage over the ranking method whereby the researcher obtains data on the relative preferablility of alternatives as well as the preferred order. In other words, when the alternatives are ranked, the research has no information as to how much the respondent prefers alterative 1 to alternative 2. However, in the rating method, respondents provide information regarding their preferences for products or services in proportion to the other products offered. For example, there are three alternatives: alternative 1, hotel with pool; alternative 2, hotel with gym and no pool; and alternative 3, hotel without pool or gym. A respondent might rate these alternatives according to their likelihood of purchase as follows: Alternative 1, 80%; Alternative 2, 85%; and Alternative 3, 40%. If these alternatives were ranked, the hotel with gym would be the first choice, the hotel with pool the second, and the hotel without exercise facilities would be third. However, the rating adds information to this study, in that the researcher knows that either a pool or a gym increase the respondent's willingness to buy with almost equal values above the hotel without exercise facilities, and therefore are almost equal contenders for these added services.

3. Choice-based Analysis. This is generally referred to as choice-based conjoint analysis (Lehmann, et. al., 1998). In this category of data collection methods, respondents are presented with sets of alternatives from which they choose one alternative per set. For example, a choice set may contain the following hotels:

(1) with restaurant and pool. (2) with restaurant, bar but no gym or pool, (3) with restaurant, bar, pool and gym, or (4) no food, drink or exercise facilities. The respondent must choose one of these four choices. This method is used extensively in this thesis and will be discussed in detail below.

4. Preferred or Considered Alternatives. This is a more relaxed form of the choice-based method. The respondents indicate which alternatives (from a given set) they would consider buying. In this case, more than one alternative can be chosen from a set. In the context of this thesis, this method would model the process of creating a short list of firms, who would then be invited to make a presentation or be interviewed in more detail.

Full profile models and ordinary least squares regression analysis has been the most common analytical tool for traditional conjoint approaches. (Green and Srinivasan, 1978; Wittink and Cattin 1989). Full profile models require that every single combination of attribute levels be included in the ranking or rating task. This method drastically limits the number of attributes and levels that are manageable and reasonable. However, to improve and expand the usability of conjoint measurement, other models have been developed. For instance, hybrid conjoint measurements include: Green's hybrid conjoint analysis (Green, Goldberg and Montemayor 1981); adaptive conjoint analysis (ACA), (Johnson 1987); and customized conjoint analysis (CCA).(Srinivasan and Park 1997; Sattler and Hensel-Borner 1999).

In general, hybrid models combine self-explicit ratings with conjoint studies. For a self-explicit exercise, the respondents rate the attributes independently, away from the context of the product as a whole. For instance, in the hotel study, one might rate the importance of a pool versus no pool. Then, in the second section of the survey, the conjoint analysis combines the attributes into alternatives, and the respondents indicate their preference rating or ranking for hotels with the listed set of attributes. The hybrid models allow the researcher to relax the need for full profile surveys.

The Marriott case is an example of a Hybrid Conjoint Study that combined the self-explicit approach with a conjoint survey. The hybrid design was necessary to account for the 50 attributes with 2 to 8 levels each. They conducted a survey and collected data on customers rating attribute levels individually, as well as comparing packages of select attributes, and having the respondents rank these alternatives in preference order. (Wind, et.al., 1989). The study objectives were to select target market segments, position services accordingly, and design facilities to improve layout and services according to customer preferences. In other words, the researchers wanted to design a hotel that potential customers deemed more valuable then the competitors.

The hotel industry is a complex service with many aspects and attributes that might influence a customer's experience. It is the author's opinion that conjoint measurement can also be used to model engineering design services. Certain aspects of these services have been identified (Appendix A), and a methodology entitled Value-Bidding is presented as to how to utilize a conjoint study.

A second alternative conjoint methodology, choice-based conjoint analysis, was developed in the 1980s (Louviere and Woodworth, 1983). This analytical method presents the alternatives in sets and requires the respondents to choose one alternative from the set. This type of respondent task is an attempt to model the actual purchase decisions made in the market place. Multinomial logit regression is often used to analyze choice data, and the details will be presented in the following sections.

4.3 State of the Art, Choice-Based Conjoint Analysis

Since Louviere and Woodworth's introduction of choice-based conjoint analysis into the marketing literature (1983), there have been many refinements. Though many researchers recommend multinomial probit analysis for choice data (McFadden, 1986, Haaijer, et. al, 1996), Multinomial logit regression is used more often and is the standard in commercial software (Orme, 1999). The debate and relative advantages and disadvantages of logit vs. probit analysis are outside of the scope of this dissertation. It is important to note however that probit models are empirically indistinguishable from logit analysis, (except for the extremes), and probit probabilities are very difficult to calculate as compared to logit models (Huber, et. al., 2000). Consequently, logit analysis is more commonly used for choice-based conjoint studies. For these reasons, logit regression is used in the data analysis for this thesis.

The important question with regard to the Value-Bidding model presented in the next 4 chapters is the accuracy of the conjoint study's prediction of the probability of winning. This probability is used as a metric for decisions and optimization throughout the engineering design procurement process. However, for Value-Bidding, any conjoint methodology could be used to develop the attribute utilities and the probability of winning, and the methods should be chosen based on the particulars of the study at hand. The user should choose a conjoint method that best suites the industry and sector under study.

Choice-based conjoint analysis was chosen to support the Value-Bidding theories developed and presented in this dissertation. Reasons for using choice-based conjoint analysis include:

1. Choice-based analysis simulates the decisions owners make when choosing a design firm
2. Choice-based analysis produces probabilities of winning over competitors, as opposed to ranking or rating based conjoint studies, where choices must be simulated based on the part-worths.

Furthermore, Joel Huber, Business School Professor at Duke University, argues for the use of choice based analysis throughout his recent research (Huber, et. al., 2000, 1986 and 1982). He presents a number of arguments in favor of choice, though he admits that it is a complex and noisy variable to study. For instance, in 1982, Huber and others presented a study where choice data captured context effects that judgment or preference rating and ranking data did not detect. Context effects are the phenomenon where the members of a set will influence a respondent's choice. For instance, a customer might weight the importance of a pool differently based on the other hotel options present. If the other options have a pool, the presence of a pool may not be a major advantage, but if alternative hotels do not have a pool, then a pool represents more of an advantage. The conclusion of Huber's evidence is that choice data reflects the decisions consumers make in the marketplace, and captures many of the complex and subtle effects on choice that rating and ranking data does not capture.

However, there are also limitations associated with choice-based conjoint analysis. One criticism of the traditional choice-based analysis is the aggregation of individual's data. If the individuals in the survey have heterogeneous preferences, the aggregate results can be misleading (Louviere, 1994). However, recent developments have been developed in an attempt to overcome this problem. Latent Class analysis and K-logit recognizes clusters and segment-based differences in respondent data, whereas ICD (Individual Choice Estimation) identifies individual respondents (Orme, 1999). If it is believed that there is possible heterogeneity in the sample population, it is recommended that an individual-level conjoint model be used, and the choice predictions be made using choice simulators.

4.3.1 Multinomial Logit Regression

Choice data is binomial. Either the alternative is chosen, Y=1, or not chosen, Y=0. Logit regression is ideal for this type of variable. The following explanation was adapted from Regression with Graphics, by Lawrence Hamilton. Let P(Y=1) denote the probability that the alternative is chosen. Conversely, P(Y=0) is the probability that the alternative is not chosen, and is equal to one minus P(Y=1).

4.2 $$P(Y \neq 1) = P(Y = 0) = 1 - P(Y = 1)$$

The odds, Θ, of the alternative being chosen is equal to the probability of Y=1 over the probability of Y =0.

4.3 $$\Theta(Y = 1) = \frac{P(Y = 1)}{P(Y = 0)} = \frac{P(Y = 1)}{1 - P(Y = 1)}$$

For example, if 700 people were studied for a hotel survey, and 500 people chose the hotel with a bar and a pool, and 200 people didn't, then the odds of the next customer choosing the hotel with bar and pool would be 5 to 2.

We now define a logit as the natural logarithm of the odds:

4.4 $$L = \log_e \Theta(Y=1) = \log_e \left\{ \frac{P(Y=1)}{1-P(Y=1)} \right\}$$

Similar to linear regression, logit regression is the combination of independent variables. However, in logit regression the logit variable is the dependent variable. The simplest assumption is that the logit is a linear function of X variables:

4.5 $$L_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_{K-1} X_{iK-1}$$

where X represents the attribute levels with K-1 attributes. Consequently, the probability, P, is nonlinear and has a curve similar to that shown if Figure 4.2.

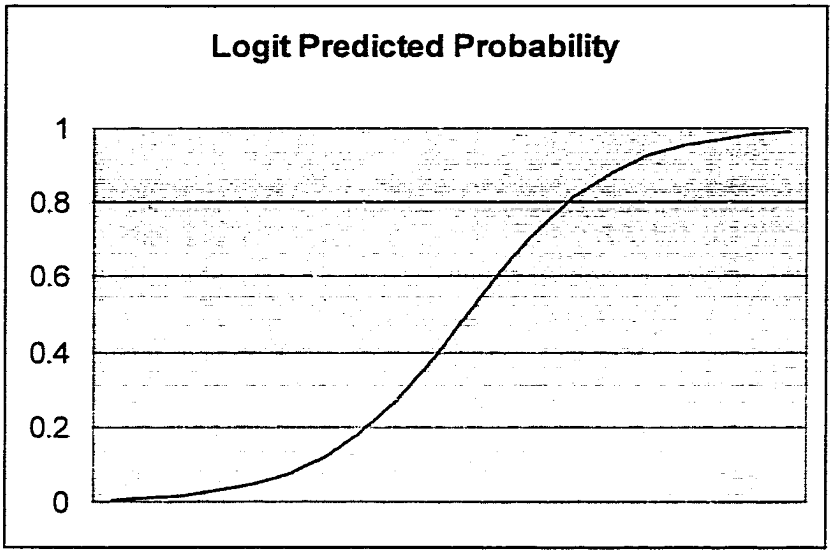

Figure 4.2 Predicted Probability of a Logit Function

The probability can be predicted by solving equation 4.4 for P(Y=1):

4.6 $$P(Y=1)=\frac{1}{1+e^{-L}}$$

Logit models are most commonly estimated using a likelihood function. A likelihood function is an expression that represents the probability of obtaining the observed sample as a function of the model parameters. To calibrate the model, i.e., solved for β_o, β_1, β_2, etc., one can maximize the likelihood function.

If we assume that the attributes in the model are independent, the likelihood function is a product of the probability that each possible alternative, i, will or will not be chosen:

$$\Gamma = \prod \left\{ P_i^{Y_i} (1 - P_i)^{1 - Y_i} \right\} \tag{4.7}$$

Taking the log of both sides, we get the log likelihood function:

$$\log_e \Gamma = \sum \left\{ Y_i \log_e P_i + (1 - Y_i) \log_e (1 - P_i) \right\} \tag{4.8}$$

Taking the first derivative of the log likelihood with respect to each of the estimated parameters, and setting each equal to zero, we derive the following simultaneous set of equations:

$$\sum (Y_i - P_i) = 0 \quad \& \quad \sum (Y_i - P_i) X_{ik} = 0 \quad \text{for k=1,2,3,... K-1.} \tag{4.9}$$

These equations are nonlinear, and therefore multinomial logit regression is an iterative process. The computer iterates over the β_k values to find the best fit.

4.3.2 Probability of Winning

Due to the nature of the logit calculations, the determination of the probability of winning is straightforward. Given a set of alternatives A, the probability of alternative, a, being chosen is equal to (Louviere and Woodworth, 1983):

4.10 $$P(a/A) = \frac{e^{L_a}}{\sum_{j \in A} e^{L_j}}$$

where L is the logit function.

Given choice-based conjoint data and logit regression analysis, engineers can calculate the probability of winning given a set of competitors. This is the theoretical foundation of the Value-Bidding model presented in Chapter 5 and 6.

References

Allison, Neil; Sean Bauld, Marie Grane, Lucy Frost, Thomas Pilon, Jon Pinnell, Rajendra Srivastava, Dick Wittink, and Peter Zandan. (1992) Conjoint analysis: A Guide for Designing and Interpreting Conjoint Studies, American Marketing Association, Chicago, 1992.

Bagozzi, Richard P. Ed., (1994). Advanced Methods of Marketing Research, Blackwell Publishers, Malden, MA, 1994. Chapter 7, Conjoint analysis written by Jordan J. Louviere.

Fishburn, Peter C., (1968) "Utility Theory". Management Science, Vol. 14, No. 5, January, 1968.

Green, Paul E., Stephen M. Goldberg, and Mila Montemayor, (1981) " A Hybrid Utility Estimation Model for Conjoint analysis," Journal of Marketing, Vol. 45, Winter, pg. 33-41.

Green, Paul E., and Vithala R. Rao, (1971) "Conjoint Measurement for Quantifying Judgmental Data", Journal of Marketing Research, Vol. VIII (August 1971), pg. 355-63.

Green, Paul E., and V. Srinivasan, (1990) "Conjoint analysis in Marketing: New Developments with Implications for Research and Practice," Journal of Marketing, Oct. 1990, pg. 3-19.

Green, Paul E., and V. Srinivasan, (1978) "Conjoint analysis in Consumer Research: Issues and Outlook". Journal of Consumer Research, Vol. 5, September 1978, pg. 103 – 123.

Gustafsson, Anders Andreas Herrmann, and Frank Huber, eds., (2000) Conjoint Measurement: Methods and Applications, Springer, New York, 2000.

Haaijer, Marinus E., Michel Wedel, Marco Vriens, and Tom Wansbeek, (1996), "Utility Covariances and Context Effects in Conjoint MNP Models", Marketing Science, Vol. 17, No. 3, 1998, pg. 236-252.

Hamilton, Lawrence C. (1992) Regression with Graphics, A Second Course in Applied Statistics, Duxbury Press, Wadsworth Inc., Belmont, CA, 1992.

Huber, Joel, A. Herrmann, and A. Gustafsson, (2000) "On the Influence of the Evaluation Methods in Conjoint Design – Some Empirical Results," Chapter in Conjoint Measurement: Methods and Applications, eds. Gustafsson, Anders Andreas Herrmann, and Frank Huber, eds., Springer, New York, 2000, pg. 183-208.

Huber, Joel, Morris B. Holbrook and Barbara Kahn, (1986) "Effects of Competitive Context and of Additional Information on Price Sensitivity." Journal of Marketing Research, vol. 23, August, 1986, pg. 250-260.

Huber, Joel, John W. Payne, and Christopher Puto (1982), "Adding Asymmetrically Dominated Alternatives: Violations of Regularity and the Similarity Hypothesis." The Journal of Consumer Research, Vol. 9, June 1982, pg. 90-98.

Johnson, Richard M. (1987) "Adaptive Conjoint analysis," Proceedings of the 1987 Sawtooth Software Conference.

Kress, George J., and John Snyder, (1994) Forecasting and Market Analysis. A Practical Approach, Quorum Books, Westport, Connecticut, 1994.

Lapin, Lawrence L., (1993) Statistics for Modern Business Decisions, Sixth Edition, Dryden Press, Fort Worth, 1993.

Lehmann, Donald R., Sunil Gupta and Joel H. Steckel, (1998), Marketing Research, Addison-Wesley Educational Publishers In., New York, 1998.

Louviere, Jordan, (1994) "Conjoint analysis", Chapter 7 in R. Bagozzi (ed.), Handbook of Marketing Research, Oxford: Blackwell, 1994.

Louviere, Jordan, David Hensher, and Joffre Swait, (2000) "Conjoint Preference Elicitation Methods in the Broader Context of Random Utility Theory Preference Elicitation Methods" Conjoint Measurement: Methods and Applications, eds. Anders Gustafsson, Andreas Herrmann, and Frank Huber, Springer, New York, 2000.

Louviere, Jordan, and George Woodworth, (1983), "Design and Analysis of Simulated Consumer Choice or Allocation Experiments: An Approach Based on Aggregate Data," Journal of Marketing Research, Vol. XX, November 1983, page. 350-367

McFadden, Daniel, (1986), "The Choice Theory Approach to Market Research," Marketing Science, Vol., 5, No. 4, Fall 1986, pg. 275-297.

Orme, Bryan, (1999), CBC User Manual, Version 2.0, Sawtooth Software, Inc. Sequim, WA, 1999, http://www.sawtoothsoftware.com

Sattler, H. and S. Hensel-Borner (2000) "A Comparisons of Conjoint Measurement with Self Explicated Approaches," discussion paper included in Conjoint Measurement: Methods and Applications, Eds. Anders Gustafsson, Andreas Herrmann, and Frank Huber, Springer, New York, 2000, pg. 121-134.

Srinivasan, V., and C.S. Park, (1997) "Surprising Robustness of the self Explicated Approach to Customer Preference Structure Measurement," Journal of Marketing Research, Vol. 34, May, pg. 286-291.

Wind, Jerry, Paul E. Green, Douglas Shifflet, and Marsha Scarbrough, (1989) "Designing a Hotel Facility with Consumer-Based Marketing Models," Interfaces, Vol. 19, No.1, January/February, 1989, pg. 25-47.

Wittink, Dick R., and Philippe Cattin (1989), "Commercial Use of Conjoint analysis: An Update", Journal of Marketing, vol. 53, July 1989, pg. 91-96.

Chapter 5

Value-Bidding, Theory and Methodology

"From the client's point of view, their perception is the truth."

-Raymond F. Kogan, strategic planning and marketing consultant, Washington D.C.

5.1 Introduction: The Selection Process

As a generalization. the procurement process for architectural and engineering design services is more complicated than in the construction industry. This is generally the case because the construction industry is primarily a low bid market. whereas the design procurement process necessitates quality selection and subsequent contract negotiations. As discussed in Chapter 3. the majority of bidding models developed for the civil engineering industry are developed for low-bid construction contracts (Christodoulou, 2000). Methodology for quality-based selection is relatively unheard of (Parks and McBride, 1987). The methodology presented in this and subsequent chapters is founded on the process surrounding the procurement of architectural and engineering services. This is not a unique process, and the methodology presented herein could be applied to any quality-based procurement process. The issues surrounding this topic are extensive and were touched upon in Chapters 1 and 2 of this dissertation. This methodology is not meant to replace intuition and common sense when deciding to prepare proposals and prices for engineering design; it is intended as a tool to support decision-making when the choices are not clear, and perhaps bring some information to light that is not evident until the research is conducted. Furthermore, it is intended to help designers manage the technological advances in this period of technological revolution, and support pricing decisions for new design processes and products. The models developed herein are based on the following procurement process:

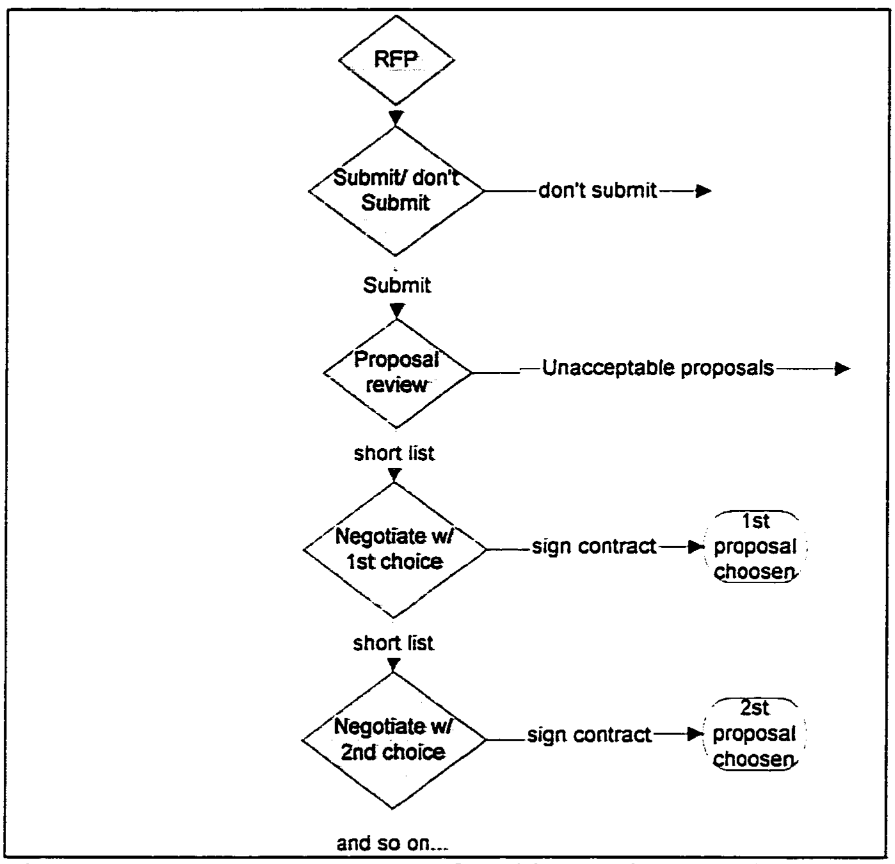

Figure 5.1 Procurement Process of Architectural and Engineering Design Services

Depending on the owner and the rules established in the request for proposals (RFP), the process can deviate from the one shown in Figure 5.1. Furthermore, the selection criterion varies from owner to owner, market to market, and season to season. As discussed in Chapters 1, 2 and 3, the Brooks Bill and state and local equivalents defines the allowed selection criteria for architecture and engineering services. However, some public agencies and all private organizations are not required to follow the Brooks guidelines. Consequently, the importance of different factors, such as design fees, has more or less weight depending on the owner organization and the selection committee. In the following development, it is assumed that different owners require a different array of services or place more emphasis on certain aspects of a design services. There are numerous types and combinations of services available in the marketplace, and some engineering firms cater to niche markets where their specialized expertise is known and welcome.

The following models are to assist any firm in the process of submitting a proposal in a competitive situation when there are numerous factors that influence their probability of winning. The price of service is rarely the only determining factor in the selection of design services. As opposed to the competitive bidding models presented in Chapter 3, which are based on price alone (selection rule: lowest bid wins), the Value-Bidding Models presented herein are based on value (selection rule: Quality/price= value wins). In essence, engineering design firms do not bid on price alone (and sometimes not at all); rather they bid on *value*. This methodology attempts to address the competitive selection process for (1) selection process without fee proposal, (Quality-based selection), and (2) selection with fee proposal (Trade-off analysis and selection). Methodology is presented for a variety of competitive proposal situations; a design firm may know the competitors, or they might not. The author adapts the competitor categories from competitive bidding theory: known competitor. average competitor and stranger. However. the author models these competitor types in a more complex and robust way, which includes qualitative factors such as firm size. employee expertise, etc. (For a complete list of attributes and levels. refer to Appendix A) The author presents methods of addressing the complexity of information regarding competitors and dealing with uncertainty and incomplete data. Chapters 5 through 9 present the Value-Bidding Model and implementation issues and criteria.

5.2 Conjoint Analysis and Attributes of Design Services

As discussed in Chapter 3. the traditional way of determining the probability of winning over known competitors is to develop a distribution for the bid to cost ratios from historical data for each competitor. This distribution can be used to calculate the probability that the contractor's bid is lower than the competitor's bid. (see section 3.3 for a detailed description)

For engineering design services. however. the traditional competitive bidding models are not applicable. In the engineering procurement process, the fee is rarely the only factor, (and sometimes not a factor in the initial decision), in the selection process. Consequently, conjoint analysis is presented as a method of developing the probability of winning over a known competitor, average competitors, and unknown competitors, given any number of factors that influence the selection process.

As discussed in Chapter 4, conjoint analysis requires the user to define the attributes of the product or service under study. In different sectors of the civil engineering industry, the attributes that influence the owner's selection process may differ. In a complicated and specialized construction project, the design technology, e.g., a three-dimensional computer model, may be an important attribute of the design service; whereas for a standard office building, a three-dimensional computer model may be perceived as excessive by the owner. It is suggested in this dissertation that conjoint analysis be used to determine the attributes and levels that owners deem most valuable, as well as the factors that are detrimental to a firm's competitive proposal.

As example, attributes of design services may include:

Personal relationship between designer and owner
Firm's technical expertise (i.e., experience with type of job)
Firm size
Total size (partnerships and subsidiaries)
Branch size (proposing for job)
Other services offered in-house
- program management
- construction
- equity capital
- commissioning
- operations and maintenance
- decommissioning

Figure 5.2 Potential Attributes of Design Services

A comprehensive list of potential attributes associated with engineering design services is included in Appendix A.

Realistically, conjoint models have only a few factors, and it is recommended that preliminary research be done to determine what the most important attributes are (Allison, et. al. 1992). However, there have been conjoint studies with as many as 50 attributes, such as the Marriott Courtyard Hotel study done in 1989 (Wind et.al., 1989). In the case of a full factorial study, a large number of attributes is unfeasible and contributes to simplification effects, e.g., recipients may simplify the task in some cases by comparing only a few of the attributes, while essentially ignoring the rest. For choice-based conjoint analysis, which is a full factorial model that is utilized in this dissertation, the realistic number of attributes is 5 or 6 (Orme, 1999). All of the attributes are displayed together, and the respondent must compare alternatives based on the sets of attributes.

As introduced in Chapter 4, the output from a conjoint analysis study are weighted values that represent the relative value consumers place on a test set of attributes and levels of the product or service under study. For instance, using some of the example attributes of design services presented above, figure 5.2, a conjoint study might generate the following utilities.

Attribute	Level	Utility (weight)
Services offered in-house		
Program management	have / do not have	42 / –23
Construction	have / do not have	35 / –15
equity capital	have / do not have	30 / –12
Firm size		
Total size (partnerships and subsidiaries	International	15
	National	12
	Local	13
Branch size (proposing for job)	Corporate Headquarters	10
	Regional Branch Office	8
	Project Office	9
Personal relationship between designer and owner		
	Worked several jobs, positive experience	65
	Worked one job, positive experience	35
	Worked no previous jobs together	–9
	Worked one job, negative experience	–23
	Worked several jobs, negative experience	–68

Table 5.1 Example Attributes, Levels, and Utilities for Engineering Design Services

Utilities represent the weight or value that the client places on the attribute level. A design firm's competitors can be modeled as a set of attribute levels, and the utilities can be summed to determine the total utility the client most probably attributes to the competitor.

Competitor 1
In-house: Project management & construction
Firm Size: International & regional branch office
Personal relationship: One previous job, positive

$U_{Competitor\ 1}$ = Project management (Util 42) + Construction (Util 15) + Equity capital (Util –12)+ International(15) + Regional branch office (8) +One job, positive (35)

$U_{Competitor\ 1} = 103$

Competitor 2
In House: Equity Capital
Firm Size: Local & Headquarters
Personal Relationship: No previous jobs

$U_{Competitor\ 2}$ = No project management (-23) + No construction (-15) + Equity (30) + O&M (2) + Local (13) + Headquarters (10) + No previous jobs (-9)

$U_{competitor\ 2} = 10$

$U_{Competitor\ 1}$ >U (Competitor 2), therefore, Competitor 1 would be preferred.

Figure 5.3 Example Utility Comparisons Based on Conjoint Analysis Output

The above example illustrates the simple analysis involving average utility values. Utilities vary across respondents, and different clients prefer different alternatives.

Therefore, more complex analysis is conducted to determine the market segmentation and consumer choice preference probabilities. After the attribute level utilities are estimated, conjoint simulators transform this raw data into useful models that can predict market choice (preference distributions) and detect segments in the marketplace (Orme, 1999).

Multinomial Logit Analysis is most often used to estimate choice probabilities for choice-base conjoint studies. The probability of choosing one alternative over other alternatives in a given set, k, can be expressed as:

$$P_a(win/\text{set k}) = \frac{\exp(U_a)}{\sum_{j=1}^{J}\exp(U_j)} \tag{5.1}$$

where U is the logit function and the sum of the utility values.

Therefore, conjoint analysis can be utilized to estimate the probability of winning given the characteristics of a design firm and its competitors. An owner study must be conducted to calibrate the model.

5.3 The General Value-Bidding Model

The Value-Bidding Models presented in the next four chapters are based on theoretical developments from the marketing and construction management literatures. Concepts and equations from conjoint analysis and competitive bidding are utilized in the development and deployment of the Value-Bidding Models. There are numerous possible variations and uses of Value-Bidding, many of which are introduced in this dissertation, Chapters 5 through 8. The Value-Bidding Model can be applied to the decision process wherein the design engineer decides whether or not to submit a proposal. Furthermore, models are presented to assist in the development of competitive proposals. Design firms may have different goals for each job for which they develop a proposal. One goal might be to win the job. A second might be to gain entry into a new geological territory or technical area. A third could be that the firm may want to maximize profit. Different models and metrics are presented for each scenario. Furthermore, the Value-Bidding methodology is valuable in a broader sense. The Value-Bidding Model presented here can assist the design engineering in determining the significant factors that influence the selection process. As it is presented and defined in this dissertation, Value-Bidding compares the designer's attributes with the competition to gain insight on the corporate strengths and weaknesses. The process of collecting and analyzing the data provides the design firm with a valuable picture of the current market and the competition. Finally, the process of conducting Value-Bidding analysis can provide designers with insights into the future trends of their markets, and give them a competitive edge.

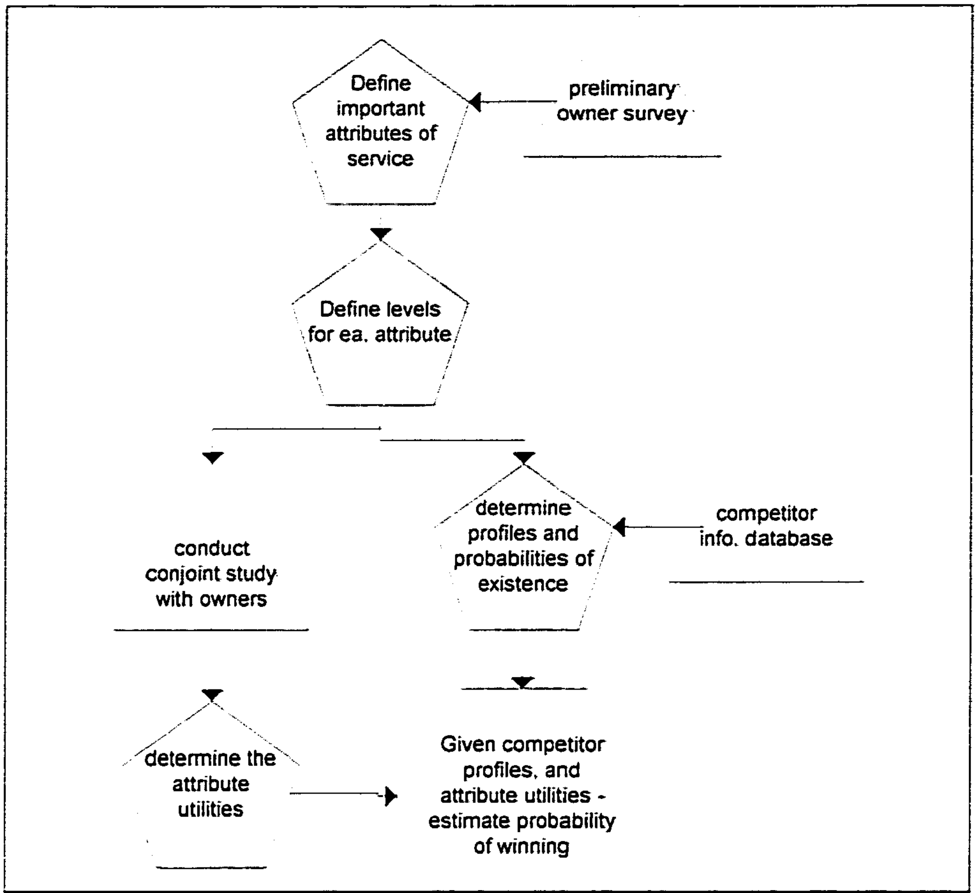

Figure 5.4 Process to Estimate the Probability of Winning

5.3.1 Probabilities of Winning and the Probabilities of Existence

To support the Value-Bidding Model, the underlying probability models are now presented. These probability models are hybrids of conjoint analysis and competitive bidding. These models include the use of the probability of winning from conjoint analysis with the competitive bidding theory developed for construction management. This is not a straightforward combination of the two models, and there are several considerations and modifications that need to be made.

Conjoint analysis alone has the potential to provide design engineering with market information, such as owner preferences and utilities (Gelb, 1988). However, one limitation to the use of conjoint analysis to model design procurement processes is the fact that the conjoint models assume that the attribute levels are discrete. In reality, a design firm has imperfect knowledge about their competitors, and this introduces uncertainty into the estimation of attributes and levels when forming alternative profiles. Furthermore, attributes, such as fee, are variable and may change depending on the competition's cost estimates, desire to win the contract, and its competitive advantage(s). Consequently, we must incorporate stochastic variables with conjoint analysis to predict more accurately the probability of winning from conjoint studies in design services.

The output of conjoint analysis and market simulation includes the probability of winning given a set of competitors, j, with a fixed set of attributes, $P_o(win/\text{set } j)$. Some of the attributes are not deterministic, and therefore, there are a number of different alternative profiles for each competitor with various likelihood of occurrence. The author defines the probability of existence to be this likelihood of occurrence.

For example, the designer might estimate that a competitor will submit a fee of 5% with a probability of 10/100, and 5.5% with a likelihood of 30/100, a fee of 6% with a chance of 40/100, and a fee of 6.5% with a probability of 20/100. In the following discussion, the author presents a model to account for this type of discrete uncertainty. In general, the attributes can be denoted as $\alpha, \beta, \ldots \zeta$, whose levels range from 1–A, 1–B, ... 1–Z, respectively. Recall from Chapter 4 that an alternative is a set of attributes at given levels, e.g. from Figure 5.3, alternative one consisted of: In-house (Project management & construction), Firm size (International & regional branch office), and Personal relationship (One previous job, positive). And, for choice-based conjoint analysis, the alternatives are presented in sets for comparison. In the context of the selection process of engineering design, competitor sets are made up of alternatives that represent the different competitors who plan on submitting proposals. If the attributes that make up the alternatives (competitors), are stochastic, then the competitor sets are stochastic. In other words, more than one set of competitors exist with certain likelihood of existence.

There is a need to incorporate the probability of the existence of different competitor sets, P (set j) into the probability of winning the contract. Consequently, the author defines the probability of existence, P (set j), as the probability that alternative profiles will best reflect the sets, j, of competitors. If the probability of winning, $P_o(\text{win/set j})$ can be determined from the conjoint simulation, and the probability of the existence of set j can be defined and is denoted as P(set j), then the probability of winning can be written as:

(5.2)

$$P_o(\text{win}) = P_0(\text{win/set 1}) * P(\text{set 1}) + P_o(\text{win/set 2}) * P(\text{set2}) + \ldots + P_o(\text{win/set k}) * P(\text{set k})$$

$$P_o(win) = \sum_{j=1}^{k} P_o(win/\text{set } j) * P(\text{set } j)$$

given k number of possible sets of competitors and their stochastic attributes.

The derivation of this equation is based on the fundamental properties of probability. It involves two rules of probability:

1) The Multiplication Rule of Probabilities
2) The Addition Rule of Probabilities

First. given two events. A and B. multiplication rule dictates that:

(5.3) $$P(A \cap B) = P(A / B) * P(B)$$

If we designate event A as the probability of winning. and event B as the existence of set j. then. the intersection of the probability of winning and the probability of set j's existence is then equal to the multiplication of the probabilities of these two events.

(5.4) $$P(A \cap B) = P(A / B) * P(B) = \text{P(win/set j)} * \text{P(set j)}$$

A Venn diagram could illustrate the sample space for the probability of winning. and the probabilities of profile sets existence:

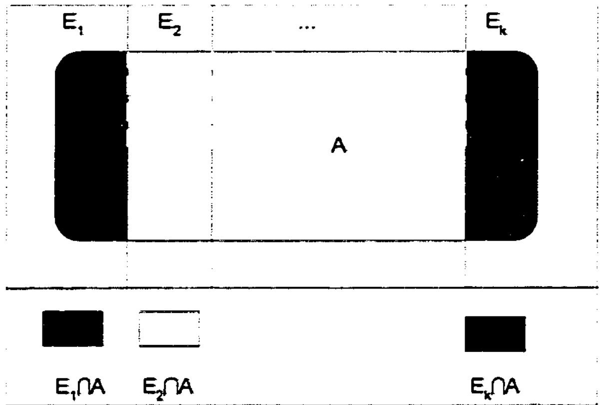

Figure 5.5 Venn Diagram for $A \cap E_1, A \cap E_2, \ldots, A \cap E_k$, if Events E_j, j=1 to k, are Mutually Exclusive and Collectively Exhaustive Events.

In this diagram, event A represents the probability of winning the contract, and events E_1, E_2, ... E_k, represent the probability of the existence of competitor sets. We assume that the events E_1, E_2 ... E_k are mutually exclusive and collectively exhaustive, and it is known that:

(5.5) $$(E_1 \cap A) \cup (E_1 \cap A) \cup \ldots \cup (E_k \cap A) = A$$

The rule of addition dictates that if the events are mutually exclusive, given two events, C and D, the probability of event C and/or the event D occurring is equal to the sum of the probability of C and the probability of D.

(5.6) $$P(A \cup B) = P(A) + P(B)$$

Given any number of mutually exclusive events, events F_1, F_2 ... F_k, the additive rule dictates that:

$$(5.7) \qquad P(F_1 \cup F_2 \cup ... \cup F_k) = P(F_1) + P(F_2) + ... + P(F_k)$$

We can designate the event F_k as the intersection of the probability of winning and the probability of set k's existence. Furthermore, it is possible to assume that the event, the intersection of probability of winning and probability of the existence of set j, P(win ∩ set j), is mutually exclusive from the second event, the probability of winning and the existence of set m, P(win ∩ set m). For the complete sample space, competitor sets 1 – k, the equation can be written as:

$$(5.8) \qquad P((win \cap set1) \cup (win \cap set2) \cup ... \cup (win \cap setk))$$

$$= P(win \cap set1) + P(win \cap set2) + ... + P(win \cap setk)$$

From the Venn diagram and equation 5.8, we can conclude that:

$$(5.9) \qquad P((win \cap set1) \cup (win \cap set2) \cup ... \cup (win \cap setk)) = P(win)$$

and,

(5.10) $$P(win) = P(win \cap set1) + P(win \cap set2) + ... + P(win \cap setk)$$

From the multiplication rule (equations 5.3 and 5.4), we can write:

(5.11)

$$P(\text{win}) = P(\text{win/set 1}) * P(\text{set 1}) + P(\text{win/set 2}) * P(\text{set2}) + \ldots + P(\text{win/set k}) * P(\text{set k})$$

$$P(win) = \sum_{j=1}^{k} P(win/\text{set } j) * P(\text{set } j)$$

which is the equation presented above, (5.2)

Not only can the competitor's attributes vary, but the attributes for the design firm using the model might vary as well. Therefore, to specify the possible variations surrounding the designer's proposal, we add a subscript to the equation: P_0(win/set j). This notation symbolizes the attribute levels for the design firm, P_0 as well as the attribute levels given to the competitors, set j.

5.3.2 Alterative Equations for Value-Bidding Calculations

An alternative set of equations can be used to determine the probability of winning over a set of k competitors. There are several cases were it would be prohibitively difficult to develop the probability of existence for complete sets of competitors. A simpler approach might be to consider each competitor individually. Just as before, some of the attributes, denoted by α,β,χ, ..., could be stochastic, and we should weigh the probability of winning by the probability of existence for each set of attribute levels. This time, the probability of winning is determined for a single competitor using conjoint simulation. The probability of existence is based solely on the attribute levels under consideration for the given competitor i. Thus, the probability of winning over a single competitor, i, can be written as:

(5.12) $$P_{o,i}(win) = \sum_{\alpha=1}^{A}\sum_{\beta=1}^{B}\dots\sum_{\zeta=1}^{Z} P_{o,i(\alpha,\beta\dots\zeta)}(win) * P_i(\alpha,\beta\dots\zeta)$$

where the Greek letters α,β,...ζ represent the competitor's attributes, each with A,B & Z possible levels respectively. $P_{o,i}(win)$ represents the probability of winning over the ith competitor, given the oth set of attribute levels for the design firm. In other words, the subscript 'i' represents the competitor, and the subscript 'o' represents the design firm's attribute levels, which may vary as well. If the design firm's attributes vary, the Value-Bidding Model can be used to find the optimal combination of levels. This will be discussed further in Chapters 7,8 and 9.

If all attributes are deterministic, than the probability of existence, P(α,β,...ζ), is equal to 100 percent, and therefore, the probability of winning, $P_{o,i}(win)$ could be calculated directly from the conjoint simulation.

In review, as the attribute levels change, the conjoint simulation recalculates a probability of winning over a single or set of competitors. The probability of competitor set existence or attribute level existence, must be determined, and then the probability of winning is modified to account for the uncertainties involved in estimating the competitors' attribute profiles.

The probabilities of winning over a single competitor, $P_{o,i}(win)$, can be combined with the well-known and tested equation proposed by Gates, 1967 (from 3.Y) to estimate the total probability of winning.

(5.13) $$P_o(win) = \frac{1}{1 + \sum_{i=1}^{n} \frac{1 - P_{o,i}(win)}{P_{o,i}(win)}}$$

This equation, the Gates' equation, was derived in Chapter 3.

Once the probabilities are determined, the calculations are fairly straightforward. However, the challenge of these models is to develop the attribute profiles for competitors, and the probability of these profiles' existence. Several methods are presented to acquire and manage profile information in Chapter 6 and Appendix B.

5.3.3 Model Refinement

There is a probability that even if a competitor shows interest in the initial stages of the RFP, they may decide not to submit a proposal for the project. This probability can be incorporated into the probability of existence. For example, if there is a 30% chance of a competitor not submitting a proposal, and the probability of winning over a competitor who does not submit a proposal is 100%, then

(5.14a)

$$P(win \cap compl) = P(win / compl - noshow) * P(noshow) + P(win / compl other) * P(others)$$

$$P(win \cap compl) = (1.00) * (3.0) + P(win / compl other) * (.7)$$

or

(5.14b)

$$P_{o,t}(win) = P(win / noshow) * P(noshow) + \sum_{\alpha=1}^{A} \sum_{\beta=1}^{B} \cdots \sum_{\zeta=1}^{Z} P_{t,(\alpha,\beta \ldots \zeta)}(win) * P(\alpha, \beta \ldots \zeta)$$

$$P_{o,t}(win) = (1.00) * (.30) + \sum_{\alpha=1}^{A} \sum_{\beta=1}^{B} \cdots \sum_{\zeta=1}^{Z} P_{o,t,(\alpha,\beta \ldots \zeta)}(win) * P_t(\alpha, \beta \ldots \zeta)$$

5.4 Implementing Value-Bidding

The application of the Value-Bidding probabilities of winning varies depending on the competitive scenario. The equations and decision metrics differ greatly depending on whether or not the fee is a selection factor or not. Consequently, we have two selection criteria cases:

1) Selection without fee (Quality-based selection)
2) Selection With fee (Trade-off selection)

Furthermore, there is a limited amount of resources a design firm can invest in market research. The development of competitor profiles and probabilities of existence vary depending on the knowledge attained regarding competitors. Consequently, the author modifies the concept of the average competitor and stranger or unknown competitor from competitive bidding theory. Consequently, three types of competitors include:

1) Known Competitor
2) Average Competitor
3) Unknown Competitor

The first step is to decide whether to submit a proposal in competition for a contract:

Decision (1) Submit a proposal?

If the design firm decides to submit a proposal, there are many different goals that a design firm may have when answering a RFP. These goals generally fall into one of three categories:

1) Win the job
2) Enter new geographic or technical territory
3) Maximize profit.

The following chapters address each of these issues in turn. Chapter 6 describes the development of models for known competitors, average competitors, and strangers or unknown competitors and discusses methods of data collection and competitor profiling. Chapters 7 and 8 discuss each of the three goals in turn: winning the job; entering new territory; and maximizing profit. The decision to submit a proposal or not is addressed under each scenario; and, the two cases, selection without fee proposal, and selection with fee proposal, are discussed within the context of each goal scenario. Finally, an example case study is illustrated in Chapter 9. This case study reviews the process of owner interviews and surveys, the development of attributes and levels and the calculation of utilities and probabilities of winning. A computer code is developed to perform the Value-Bidding calculations. Furthermore, competitor profiles are developed, and the models are tested for predictability in terms of the design firm selected. Correlations between the utilities and fees are also studied to test the hypothesis that a firm with high utility can charge a higher fee than a firm with lower utility. The model's predictions are compared to the actual outcomes, and the model performs favorably.

References

Allison, Neil; Sean Bauld, Marie Grane, Lucy Frost, Thomas Pilon, Jon Pinnell, Rajendra Srivastava, Dick Wittink, and Peter Zandan, (1992) Conjoint analysis: A Guide for Designing and Interpreting Conjoint Studies, American Marketing Association, Chicago, 1992.

Christodoulou, Symeon, (2000) "The Science in Human Intuition: Optimum Bid Markup Calculation in Competitive Bidding Environments Using Probabilistic Neural Networks", working paper.

Gelb, Gabriel, (1988) "Conjoint analysis helps Explain the Bid Process", Marketing News, American Marketing Association, Vo. 22., No. 6, March 14, 1988, pg. 1 and 31.

Orme, Bryan, Ed. (1999) CBC User Manual, Version 2.0, Sawtooth Software, Inc. Sequim, WA, 1999. http://www.sawtoothsoftware.com

Parks, Gary A., and Robert R. McBride, "Competitive Bidding for Engineering Services", Journal of Professional Issues in Engineering, Vo. 113, No. 1, January 1987, pg. 66-76.

Wind, Jerry, Paul E. Green, Douglas Shifflet, and Marsha Scarbrough, (1989) "Designing a Hotel Facility with Consumer-based Marketing Models", Interfaces, Vol. 19, No. 1, January/February, 1989, pg. 25-47.

Chapter 6

Development of Models for Known Competitors, Average Competitors, and Unknown Competitors

Compare, v., :

to examine in order to observe or discover similarities or differences.

-Webster's NewWorld Dictionary, 2nd, Ed. 1970.

6.1 Introduction

The development of competitor profiles is a critical and often difficult part of Value-Bidding. As discussed in Chapter 5, the first step in any conjoint study is to determine the attributes, which influence the clients' purchase choices. Then, model developers must determine levels for these attributes. (Potential attributes and levels are presented in Appendix A). After the conjoint study is defined, and the data collected from the owners, the Value-Bidding Model user must develop competitor profiles, collections of attribute levels, that best represent the status of competitors.

Due to the limitations on the availability of information and the resources a firm can dedicate to information gathering, researchers have developed the concepts of known, average and unknown competitors (Friedman, 1956; Gates, 1967).

a. Known competitor. A competitor who is often encountered in a competitive proposal process, and who should be researched to develop a unique Value-Bidding profile.

b. Average competitor. A competitor who is sometimes encountered in a competitive proposal process, but does not merit detailed research. The average competitor is modeled with a profile that represents an average over all typical competitors.

c. Stranger or Unknown competitor. A competitor who has never been encountered previously in a competitor proposal process. This profile reflects the uncertainty implicit in the situation when there is no information available on this competitor.

In any industry, a firm (designated as Firm A) may identify other firms (Firms X, Y, Z) who are direct competitors to the services offered by Firm A. These direct competitors can be designated as known competitors. Known competitors are often in competition for the same jobs as Firm A. The Value-Bidding Model requires that Firm collect information about these known competitors, Firms X, Y and Z, in order to develop profiles that describe their services.

The type of information Firm A should gather can be diverse, (see appendix A) and the reliability of this information may be fair or poor; the data may be comprehensive or incomplete. In this chapter, the author recommends methods of gathering data and modeling competitor profiles in light of the uncertainties involved in this process.

Known competitors are generally those firms that often appear as competitors on specific projects. However, there are a number of other firms (Firms M,N,O) who appear occasionally. The rare to occasional appearance of Firms M, N and O does not necessitate a thorough data collection effort. Instead, the profiles for Firms M, N and O can be determined as average competitors. The profile for an average competitor would reflect the attribute levels that define the majority of Firm A's competitors. Issues and aspects of developing the average competitor profile are addressed in Section 6.3.

Occasionally, firms submit proposals in competition with other firms whom they know nothing about. Either the unknown firm is trying to enter a new market and is not familiar with all of the competitors, or Firm A is in competition with a new firm entering a well-known market. The more specific the user defines competitor profiles, the more accurate the results can be; however, when time and resources are limited, Firm A may need to include unknown competitors into the model. This special case is discussed in Section 6.4.

One of the contributions described in this dissertation is the development of the probability of winning against competitors in both a quality-based selection process, (without a fee proposal), and in a trade-off selection process (with fee proposal). The owner's selection of a design firm is generally based on a number of attributes, and the probability of winning will be developed based on these attributes. In order to assess the probability of winning, a firm must choose aspects that describe the competitive elements of the engineering service. Factors that influence the selection of the design firm might include those listed in Appendix A. Once the key attributes are chosen, the profile for each known competitor can be developed. The attributes chosen by Firm A dictate the type of data collected regarding their competitors.

6.2 Known Competitors

There are competitive bidding models in the construction literature that deal with known competitors (Friedman, 1956; Gates, 1967; King and Mercer, 1985; Carr, 1982; Stark and Rothkopf, 1978). These competitive bidding models, however, focus on gathering data pertaining to past bids of competitors in the construction industry. Other information is not systematically collected or incorporated into the bidding model. Value-Bidding requires that the user collect information about the competitors relating to any number of attributes (Appendix A). For example, key attributes might include services offered in-house, firm size, and personal relationship with owner. The data that could be collected for common competitors might consist of the following:

Competitor 1 – ABC Design and Construction Company			
Attribute	**Level**		
Attribute 1. Services offered in-house		Have service	Do not have service
	program management	✓	
	construction	✓	
	procurement	✓	
	equity capital		✓
	commissioning		✓
	operations and maintenance		✓
	decommissioning		✓

Attribute 2. Firm size			
	Total size		
		Local	
		National	✓
		International	
	Branch size		
		Headquarters	
[redacted]		gional office	✓
		Job office	

Attribute 3. Personal relationship between designer and owner		
	Worked several jobs, positive experience	✓
	Worked one job, positive experience	
	Worked no previous jobs together	
	Worked one job, negative experience	
	Worked several jobs, negative experience	✓

Table 6.1 Example Profile for Competitor ABC Design and Construction

Table 6.1 shows an example of a hypothetical profile for a company. The first two attributes are fairly easy to define for any given competitor. The type of services a firm offers is published in their promotional literature, and the office size is included in the company statistics in the Blue Book and other industry lists (see Appendix B). The third attribute, previous work with owner, is more difficult to define with absolute confidence.

It is suggested herein that a firm who is implementing a Value-Bidding methodology, will need to establish a databases to systematically gather information similar to Table 6.2. If Firm A were to include attribute 3 from Table 6.1 in their Value-Bidding regime, they would need to log information from many different sources. One might find out if the firm has worked with an owner from trade magazines, corporate literature, professional organizations, and personal correspondence. Over time, the information collected will be more and more accurate.

Owners ⇒ Competitors ⇓		Owner A	Owner B	Owner C	Owner D
Competitor ABC Design & Construction	*Address*	320 Main St.		airport runway D	
	Actual – Budgeted cost	$2 million over budget		$100 thousand under	
	Schedule	1 mo. over		met schedule	
Competitor Engineering Design Technologies, Inc.	*Address 1*	530 Center St.	430 Ridge Dr.		2nd and Main
	Actual - Budgeted cost 1	$10 thousand over	$30 thousand under		$1 million over
	Schedule 1	On schedule	One month early		2 months over
	Address 2				3rd and Arizona
	Actual - Budgeted cost 2				1.5 million over
	Schedule 2				3 months over

Table 6.2 Examples from a Database for Competitor's Projects with Owners and Indicators of Success

Some of the attributes are deterministic, e.g. services offered and firm size, but other attributes are not as straightforward, e.g. past experience with owner, and the levels must be estimated. The error introduced when estimating the profile levels for a competitor creates stochastic variables. For example, the firm's size is a deterministic variable and can easily be determined from public sources, e.g. corporate website. Is the firm large or small, national or international? In-house services are also fixed, i.e., project management, project development, construction, and cost estimation. Either the competitors offer these services in-house or they do not. Deterministic variables can be put into the conjoint choice simulator as a fixed and certain value. However, these variables are prone to change over time. Companies are continually modifying their services to enhance their competitive advantage. The Value-Bidding databases must be continually maintained to assure accuracy.

Stochastic variables, on the other hand, make the problem more complex. Some information may not be public or published in one source; rather, information is often scattered throughout different public sources, and it is difficult to know with certainty if one has comprehensive data. As in the example in Table 6.2, competitor's previous jobs and the relative successes or failures can be found in industry journals and publications, (see Appendix B). Therefore, there is some uncertainty introduced into the estimate of the stochastic attribute levels. There are many attributes listed in Appendix A that are potentially stochastic.

To accommodate this uncertainty, the author acknowledges that there is a certain probability associated with different levels for stochastic attributes. These probabilities are designated as the Probabilities of Existence for each competitor. Given a certain group of attributes, there is a probability that a competitor will have a given set of attribute levels. For example, consider attribute 3, previous experience with the owner, from Tables 6.1. and 6.2. To the best of our knowledge the second competitor, Engineering Design Technologies, Inc. (EDT, Inc.) has worked on two projects for Owner D. Their projects were over budget and over schedule. Therefore, we know for certain that EDT, Inc. has worked on more than one project with Owner D, but we are not certain whether the owner was happy with EDT, Inc.'s performance or not. Since both projects were over budget and schedule, the likelihood is high that the owner is not happy with EDT, Inc.'s previous performance. Therefore, we could estimate the probabilities of existence for EDT, Inc. The probability that attribute 3 - Worked several jobs, positive experience – could equal 20%, and the probability that attribute 3 – Worked several jobs, negative experience – could be 80%.

Attribute 3. Personal relationship between designer and owner		P(existence)
	Worked several jobs, positive experience	20
	Worked one job, positive experience	0
	Worked no previous jobs together	0
	Worked one job, negative experience	0
	Worked several jobs, negative experience	80

Table 6.3 Table of Probabilities of Existence for the Levels of Attribute 3, Continued from Example 6.2

The determination of the attribute probabilities of existence is subjective, and steps should be made to keep the estimations consistent, i.e., base the estimate for each competitor on the same criterion. Once the individual attribute level probabilities of existence are determined, they must be combined to define the overall probability of profile existence for a given profile. In the simple example presented above, the probabilities are as follows (it is assumed that deterministic attributes have a probability of existence equal to 100%):

Competitor 2 – Engineering Design Technologies, Inc.			
Attribute	**Level**	**Probabilities of existence**	
Attribute 1. Services offered in-house		Have service	Do not have service
	program management	100%	
	construction	100%	
	procurement	100%	
	equity capital		100%
	commissioning		100%
	Operations and maintenance		100%
	decommissioning		100%

Attribute 2. Firm Size			
	Total size		
		Local	
		National	100%
		International	
	Branch Size		
		Headquarters	
		Regional office	100%
		Job Office	

Attribute 3. Personal relationship between designer and owner		
	Worked several jobs, positive experience	20%
	Worked one job, positive experience	
	Worked no previous jobs together	
	Worked one job, negative experience	
	Worked several jobs, negative experience	80%

Table 6.4 Example Probability of Existence Profile for Hypothetical Competitor

Attributes 1 and 2 are deterministic, whereas attribute 3 is stochastic. Therefore, the probabilities of existence for each possible profile are dictated by attribute 3. Profile 1 is defined as a competitor offering project management, construction and procurement in-house, a national company with a regional office in the area, and a positive history with the owner on multiple jobs. The probability of existence for Profile 1 is 20%. Profile 2 includes the above attributes, but changes the last attribute to a negative history with the owner on multiple jobs. The probability of existence for Profile 2 is 80%.

In general, with the assumption that the attributes are statistically independent, and given any number of attributes and levels with deterministic and stochastic variables, the probability of existence for any profile can be written as:

6.1

$$P(profile_i exists) = P(attribute\_\alpha = level_j) * P(attribute\_\beta = level_j) * ... * P(attribute\_\zeta = level_j)$$

To use this probability of profile existence, we combine it with the output from the conjoint study, as discussed in Chapter 5. The conjoint choice simulator generates a probability of winning based on the profiles entered for the user and the competitors. For each competitor profile, there is an associated probability of winning as well as a probability of existence. In the example above, Table 6.4, for all of the profiles, attribute 1 and attribute 2 are constant. Attribute 3 changes after each iteration. Define, F_1 as the first profile, (attribute 3 = worked several jobs, positive experience); F_2 as the second profile: (attribute 3 = worked one job, positive experience); and in general, F_L is the profile where attribute 3 = the Lth level. The probability of the Lth profile being the true profile is notated as $P_L(F_L)$. In this example, $P_1(F_1)$=20, $P_2(F_2)$=0, $P_3(F_3)$=0, $P_4(F_4)$=0 and $P_5(F_5)$=80.

Therefore, the probability of winning over competitor one is equal to the sum of the probability of winning given the Lth profile times the probability of existence of the Lth profile. The probability of winning over the ith competitor can be expresses as:

$$(6.2) \quad P_i(win) = P_1(win) * P_1(F_1) + P_2(win) * P_2(F_2) + ... + P_L(win) * P_L(F_L)$$

given one stochastic variable F_L. This equation can be generalized for many stochastic attributes as noted in equation 5.12:

$$(6.3) \qquad P_{o,i}(win) = \sum_{\alpha=1}^{A} \sum_{\beta=1}^{B} ... \sum_{\zeta=1}^{Z} P_{o,i,(\alpha,\beta...\zeta)}(win) * P_i(\alpha, \beta ... \zeta)$$

Where $P_{o,i,(\alpha,\beta...\zeta)}$(win) is the probability of designer o, winning over competitor i, given attributes levels α,β,... ζ, and $P_i(\alpha, \beta ... \zeta)$ is the probability of competitor i's existence for the profile defined by attribute levels $\alpha,\beta,...\zeta$. This equation is only valid if we assume the attributes, $\alpha,\beta,...\zeta$, are mutually exclusive.

There may be a variety of ways that a variable is stochastic. The users knowledge may be incomplete, and therefore there is some error introduced in the estimation of the stochastic variable. Or, there might be a variety of choices that the competing firm could submit in their proposal, and the Value-Bidding user must estimate the probability of the competition's submission. Other uncertainties may arise based on the owner's perception, and the user must anticipate this perception, which introduces error.

The probabilities of existence incorporate an engineer's intuitive knowledge of the competition, the owner, and the marketplace, into competitive bidding models. Today, engineers rely on personal knowledge of owners and competitors to tailor their proposals for a specific job. The Value-Bidding Model is an attempt to quantify this intuition, document personal knowledge, and incorporate it into the proposal development and fee estimation process on a more rigorous and thorough level. The pragmatic collection of data establishes a systematic approach to evaluating one's competitive advantages and determining the best strategic approach for proposal development.

6.3 Average Competitors

To develop profiles for average competitors, the author utilizes some of the same concepts developed for the known competitors above; however, now we define an average or typical profile instead of a specific one. The probability of existence is particularly relevant for the average profile and can be used to calibrate the model for different situations and to fine-tune the model when more precise information is available. In the case of an average competitor profile, the attribute level development reflects the typical profile for any given industry sector, as opposed to the known competitor profile that represents a single competitor.

An average competitor profile could be as simple as an average of the known competitors. Many competitive bidding models developed in the civil engineering literature suggest this method (see Chapter 3, Section 3.3.2) For example, in 1956, Friedman proposed that one compile a histogram of bid-to-cost ratios for all competitors and use these ratios to develop a probability of winning function for an average bidder. For Value-Bidding, the author proposes that one can do a similar cummulative data collection effort to determine the average or typical competitor profile.

A Value-Bidding Model user has compiled data on known competitors. To develop a typical competitor profile, one could analyze this data in the aggregate by developing histograms for each of the attributes. For illustration, consider the attributes discussed in the example in section 6.2.

a. Services offered in-house

b. Firm Size

c. Personal relationship between designer and owner

A histogram of the deterministic variables is straightforward. One can simply add the number of firms whose services are characterized by each level and attribute. Given n competitors, A attributes, and J levels per attribute, the histogram can be calculated by

$$L_{aj} = \begin{Bmatrix} L_{aj} + 1 & if\ j = f_i \\ L_{aj} & if\ j \neq f_i \end{Bmatrix},$$ for a=1,2,...A, j=1,2,...J, and i=1,2,...n, where L_{aj} represents the attribute's level in the histogram. Therefore the probability of existence for any given attribute level is equal to the sum of the firms, which fall into the level's category divided by the total number of competitors. P(attribute_a=level$_j$) = $\frac{L_{aj}}{n}$.

Attribute 1. Services offered in-house	Have service	Do not have service
program management	80%	20%
construction	50%	50%
procurement	55%	45%
equity capital	25%	75%
commissioning	10%	90%
operations and maintenance	1%	99%
decommissioning	1%	99%

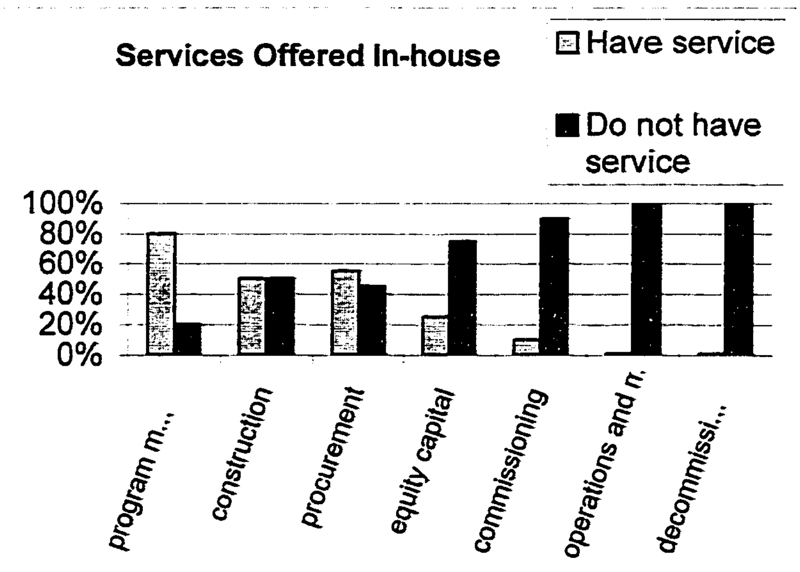

Figure 6.1 Attribute 1. Histogram for Services Offered In-House

Attribute 2. Firm Size			
	Total size		
		Local	14%
		National	36%
		International	50%
	Branch Size		
		Headquarters	23%
		Regional office	58%
		Job Office	19%

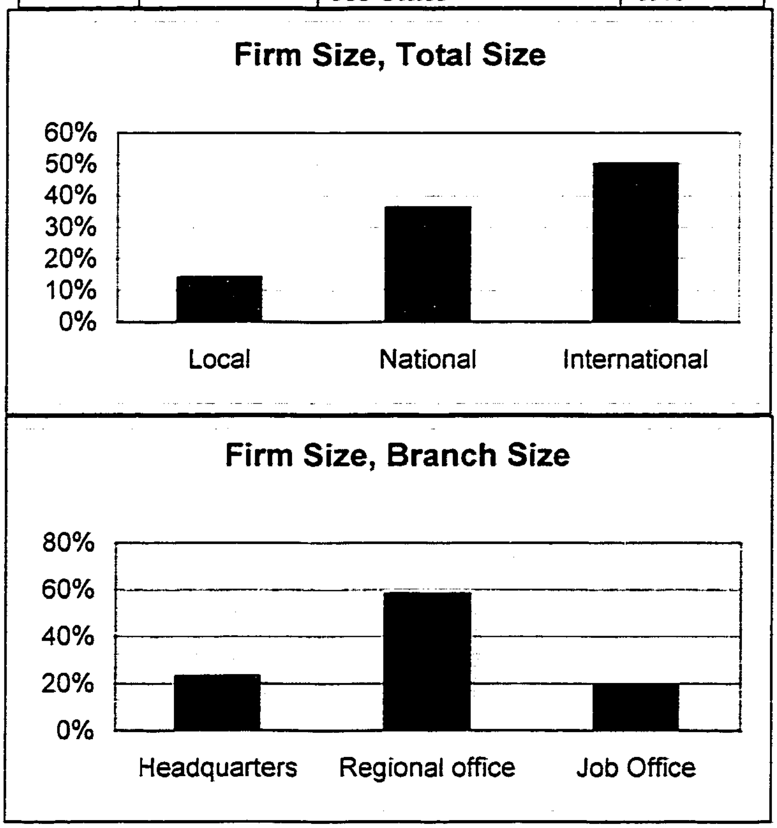

Figure 6.2 Attribute 2. Firm Size. Histograms of the Total Size and the Branch Size

In reference to the example presented in Figures 6.1 and 6.2, there is a 14% chance a typical competitor is a local firm. 36% chance they are a national firm, and 50% chance they are an international firm. These percentages can be used in developing the probability of profile existence. Recall, in Section 6.2, we used equation 6.1 to determine the probability of profile existence:

6.4

$$P(profile_i\,exists) = P(attribute\_1 = level_i) * P(attribute\_2 = level_i) * ... * P(attribute\_n = level_i)$$

This equation is valid for the average competitor as well. For example, if profile 1 is defined to include:

Attribute 1. Services offered in-house		Have service	Do not have service
	program management	✓	
	construction	✓	
	procurement	✓	
	equity capital		✓
	commissioning		✓
	operations and maintenance		✓
	decommissioning		✓

Attribute 2. Firm Size			
	Total size		
		Local	✓
		National	
		International	
	Branch Size		
		Headquarters	
		Regional office	
		Job Office	✓

Then the corresponding probability of existence would be:

P(Profile1) = P(have program management) * P(have construction) * P(have procurement) * P(do not have equity capital) * P(do not have commissioning) * P(do not have O&M) * P(do not have decommissioning) * P(total size = local) * P(branch size = job office)

= (80%)*(50%)*(55%)*(75%)*(90%)*(99%)*(99%)*(14%)*(19%) = .387%

Figure 6.3 Example Calculation for the Probability of Profile 1's Existence

It is not intuitive that this number is so small. However, there are 1152 possible profiles given 7 in-house attributes with 2 levels each (in house, not in house) and 2 firm-size attributes, 3 levels each, (Total size and Branch size).

For average competitors some simplification might be possible. For instance, for the three in-house services, commissioning, operations and maintenance, and decommissioning, a vast majority of the competitors do not offer these services, (90-99%). Therefore, as we model the average competitor, we could assume that all average competitors do not offer these services and thereby eliminate those three attributes from the model. This would reduce the number of possible profiles to 144.

Other simplifying assumptions may be possible, based on the specific project in question. The user might have explicit knowledge regarding the type of average competitors bidding on a given job. For instance, one may know that only international firms are bidding for a job in Taipei. This would eliminate the possibility of national or local firms bidding on the job. This further decreases the possible profiles. The Value-Bidding Model are flexible such that any sector or market could be modeled. The key decisions when modeling an industry sector are the choice of attributes, the data collected, and resulting competitor profiles.

Stochastic variables may be more complicated than deterministic variables; however histograms can be developed for these attributes as well. We must develop a histogram with a single observation (competitor) falling into several categories at once. As for deterministic variables, there are n competitors, A attributes, and J levels per attribute, but with stochastic variables the histogram is populated with fractions. For example, attribute 3 from the example above is a stochastic variable with a possible distribution of:

[redacted]		
Attribute 3. Personal relationship between designer and owner		
	Worked several jobs, positive experience	20%
	Worked one job, positive experience	
	Worked no previous jobs together	
	Worked one job, negative experience	
	Worked several jobs, negative experience	80%

Table 6.5 Probability of Existance for Example Attribute 3

To develop a histogram with practical observations, one should place fractions in each category while counting the number of observations. Unlike the deterministic variable, the stochastic histogram is not populated with increments (recall for deterministic variables, $L_{aj} = L_{aj} + 1 \;\; if \; j = f_i$). Now, the increments can be notated as f_{aji} for attributes, a=α,β,...ζ, levels, j = 1–A, 1–B,...1–Z, respectively, and competitors, i=1,2,...n. Consequently, the histogram levels are added according to the rule: $L_{aj} = L_{aj} + f_{aji}$. Where f_{aji} is the fractional value for attribute a, level j and competitor i. The probability of existence for an average stochastic variable is then, P(attribute_a=level$_j$)= $\frac{L_{aj}}{n}$, where n is the total number of competitors.

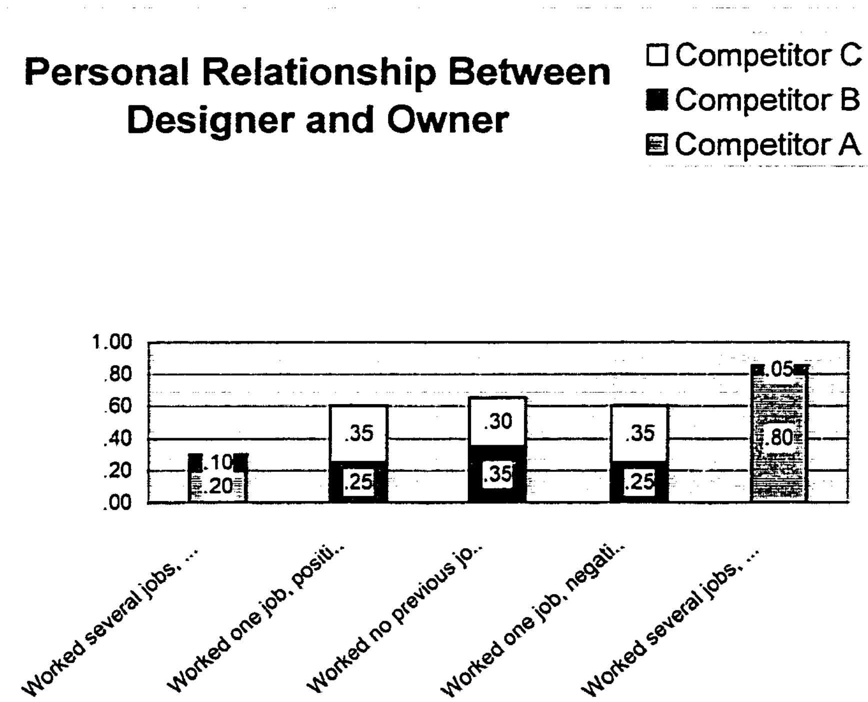

Figure 6.4 Histogram for Attribute 3, Personal Relationship between Designer and Owner

In this example, there are 3 observations, and the percentages can be calculated as follows:

Level 1: Worked Several jobs, Positive Experience = $\frac{.2+.1}{3} = 10\%$.

Level 2: Worked One Job, Positive Experience = $\frac{.25+.35}{3} = 20\%$.

Level 3: Worked no previous jobs = $\frac{.30+.35}{3} = 22\%$

Level 4: Worked One Job, Negative Experience = $\frac{.25+.35}{3} = 20\%$.

Level 5: Worked Several jobs, Positive Experience = $\frac{.8+.05}{3} = 28\%$.

Figure 6.5 Calculation for Stochastic Histogram

In this way, stochastic and deterministic variables are on common ground and can be combined into the probability of profile existence with the aforementioned equation (6.1):

6.5

$$P(profile_i exists) = P(attribute\_\alpha = level_i) * P(attribute\_\beta = level_i) * ... * P(attribute\_\zeta = level_i)$$

Once the probability of profile existence has been calculated, this probability can be incorporated into the Value-Bidding Model just as for the known competitors. Recall for known competitors the attributes were defined as α,β,...ζ with levels 1–A, 1–B, ...1–Z, and the probability of winning can be written as (6.3)

$$6.6 \qquad P_{o,i}(win) = \sum_{\alpha=1}^{A}\sum_{\beta=1}^{B}\cdots\sum_{\zeta=1}^{Z} P_{o,i,(\alpha,\beta,\ldots\zeta)}(win) * P_i(\alpha,\beta\ldots\zeta)$$

where $P_i(\alpha,\beta,\ldots\zeta)$ is the probability of existence for the profile defined by the attribute levels α,β,...ζ.

An average competitor profile may be used when an engineer's database may not include a specific competitor. However, often the probabilities of profile existence can be modified to reflect the intuition and insight a project managers has regarding the market and competition. One or two levels per attribute may describe typical competitors, thereby reducing the number of profiles in the calculation, and the full details of the calculations presented in this section can be minimized.

As with any empirical model, the more information and data collected and incorporated into the model, the more accurately the model will predict the probability of winning. The absence of information is the most frequent cause of error.

Though the Value-Bidding Model is aimed at assisting a designer in the preparation of a proposal and fee for a specific job, the exercise of collecting and analyzing the data about the competition could benefit an engineering firm by providing an insight into industry trends and provide food for thought regarding corporate goals and directions. Consequently, Value-Bidding benefits the company on specific proposals, but also provides a tool by which the company can quantify the market and competition, test acceptance and pricing for new services, as well as gain insight into a new economic, technical, or geographic area.

6.4 Strangers or Unknown Competitors

Though there is a fine line between average and unknown competitors, in this discussion and for Value-Bidding in general, the author believes a distinction should be made. Unknown competitors are wild cards. Whereas average competitors can be modeled based on the typical firm vying for a job, an unknown competitor can have any possible combination of characteristics and attributes. Many in the civil engineering literature have addressed the unknown bidder as the average bidder (Friedman, 1956; Gates, 1967; Carr, 1987). However, given the variety of attributes, and an engineer's insight into the competitive environment, the average bidder can be tailored to a specific job, whereas for the unknown competitor, we must rely on the full model, data and statistics derived by the methods described in section 6.3.

For the unknown competitor, unless there is some evidence to the contrary, the author recommends that the user of a Value-Bidding Model use a full profile computation described in detail above. A full profile computation would include every possible profile and it's associated probability of existence. The probabilities of profile existence are calculated from the histograms of known competitors in the field.

If there is not enough data to develop a histogram, a user can model either a uniform distribution across all of the levels for an attribute, or estimate a distribution based on familiarity with and knowledge of the marketplace.

An unknown competitor profile might be used when entering a new geographical or technical area where many of the competitors are unfamiliar. Perhaps a new firm enters in competition in an existing market. This new firm could be modeled as an unknown competitor.

6.5 Data Collection Issues

There is a wide variety of data that a Value-Bidding researcher may be interested in collecting. Appendix A lists a number of possible attributes that could be included in the competitor profiles. A firm who wishes to utilize the Value-Bidding Model presented in this thesis is limited by the realities of collected information regarding their competitors. Some data may be straightforward to obtain, while other data may be unavailable or incomplete. In this section, the author addresses the reality of data collection, and presents a potential source list in Appendix B.

Just as it has influenced many other aspects of business, the Internet has revolutionized market research. There are many sources of information currently available regarding competitors, and there is surely more to come in the future. Government agencies, private firms, and professional societies are linking databases and information to the Internet on a continual basis. Data clearinghouses and networking sights are eager for business-to-business accounts and are making connections between vendors and suppliers for many products and services. Unfortunately, there is no single website that presents the comprehensive information the Value-Bidding Model require. However, with careful research, a firm can document the competition on a fairly current and comprehensive basis.

There is still something to be said for hardcopy, e.g. magazines and books, and many information sources are not as yet available on-line. Industry journals and marketing research clearinghouses charge for their services, but provide a good source of information regarding competitors. The very same sources currently used in design offices to keep up-to-date on potential and future jobs may contain information regarding competitors as well. Professional societies often publish member information lists for members, and personal contacts through these professional societies often provide insights into the competition.

To develop competitor profiles, engineers must turn detective and discover all of the quantifiable information available about competitors. The analysis presented in this chapter will turn this data into a powerful modeling tool, which will help a user predict the probability of winning a job and help the firm achieve their competitive goals. However, this tool is a model and based on mathematical algorithms. There are many unknown or unstated factors not accounted for, and Value-Bidding is designed to support and enhance an engineer's decision making, but not replace intuition and common sense.

References

Carr, Robert I., (1987), "Competitive Bidding and Opportunity Costs," Journal of Construction Engineering and Management, ASCE, Vol. 113, No. 1, March 1987, pg. 151-165.

Carr, Robert I., (1982) "General Bidding Model" Journal of the Construction Division, ASCE, Vol. 108, No. CO4, December 1982, pg. 639-650.

Friedman, L., (1956) "A Competitive Bidding Strategy," Operations Research, Vol. 4, 1956, pg. 104-112.

Gates, Marvin, (1967) "Bidding Strategies and Probabilities" Journal of the Construction Division, ASCE, Vol. 93, No. CO1, March, 1967, pg. 75-107.

King, Malcolm, and Alan Mercer, (1985) "Problems in Determining Bidding Strategies" Journal of the Operations Research Society, Vol. 36, No. 10, November 1985, pg. 915-923.

Orme, Bryan, (1999), CBC User Manual, Version 2.0, Sawtooth Software, Inc., Sequim WA, 1999, http://www.sawtoothsoftware.com

Stark, Robert M. and Michael H. Rothkopf, (1978) "Competitive Bidding: A Comprehensive Bibliography". Operations Research, Vol. 27, No.2 , pg. 364-389.

Chapter 7

Proposal Goals: Win the Job

And Enter New Territory

"10% of something is worth more than 100% of nothing"

- anon.

Introduction

It has been shown that conjoint analysis alone can improve the likelihood of a bidder winning a proposal. (Gelb, 1988) Conjoint analysis gives the user the ability to assess the influences on the selection of a firm in a competitive bidding or proposal selection process. Consequently, the knowledge of the attributes of the design service that are most valued by the owner can enhance a design firm's proposal and presentation in a competitive environment. The design firm can use conjoint analysis as a guide to fine-tune their proposals and presentations and bring them in-line with the owner's interests and values. Furthermore, designers can use this knowledge to justify the price of design services.

The models presented in Chapters 5 and 6 enable the user to quantify as well as qualify the probability of winning a contract in a competitive environment. Value-Bidding is the combination of conjoint analysis, the analysis of the owner's value and perspective, and competitive marketing research, presented in Chapter 6. The next few chapters present methods of using the results of these market research techniques. From the process of estimating the probability of winning, the design firm has a better understanding of the competition as well as the owner. The design firm can capitalize on the competitive advantages that set them apart from the competition in the eyes of the owners.

Chapters 7 and 8 follow the proposal selection process from the decision to prepare and submit a proposal to the contract negotiation stage. The research methodology presented thus far, Chapters 5 and 6, can assist a design firm throughout a successful selection process. The first step is the decision whether to submit a proposal or not, whether to respond to an RFP (Request of Proposal) or not. The second is the proposal evaluation and an oral presentation. The third is the contract negotiations. Some owners request a fee proposal along with a technical proposal in the second stage, Quality-Based Selection with fee; whereas others do not discuss price until the negotiation stage, Quality-Based Selection without fee. Both scenarios will be addressed.

The fee can often be left out of the analysis of the proposal stage. There are several scenarios where this might be important. First, if the owner does not request a fee proposal. Second, if the objective is to win the job regardless of fee. In the second case, a firm should do the analysis without the fee to evaluate the competitive environment and probability of winning based on other attributes, and then compute a fee that is low enough to assure a high probability of success, but maintains the viability of the company.

This chapter addresses the goal of winning the job above all else. There might be several reasons winning a job is the main objective of proposal submission. For example, a design firm has a fixed number of employees and it is the managers' job to keep the work volume fairly even to maintain employee workloads (Griffis, 1992). Or, there might be follow-up opportunities that are particularly attractive (Paranka, 1971). Or, the firm may be attempting to enter into a new technical or geographic territory. The goal of entering a new territory is a special case of the win-the-job objective. Issues surrounding the aspiration of entering a new territory are discussed in the last section, 7.5.

7.2 Submit/Do not Submit Proposal Decision

The question we address here is the decision whether to submit a proposal or not in response to a Request for Proposals (RFP). This question and the subsequent decision-support theory are often referred to as the bid/no bid decision problem in the competitive bidding literature. Researchers have identified analytical criteria for evaluating the decision whether to enter into a competitive proposal process, (Paranka, 1971; King and

Mercer, 1985; and Ahmad and Minkarah, 1987), though the business of design engineering has rarely been addressed specifically. The following have been identified as major factors in the bid/no bid decision process (Paranka, 1971):

1. Resource Capacity
2. Competition
3. Follow-up Opportunities
4. Quantity (Volume)
5. Delivery
6. Profit

The decision to submit a proposal is often based on a design firms need for work, ability to do the work requested, and the potential profit. Value-Bidding is most valuable in determining the chances of success (probability of winning). The preliminary analysis then focuses on the competition and potential profit or loss associated with submitting a proposal. For a thorough pre-proposal analysis, Value-Bidding should be combined with analysis regarding the firm's capacity for new work (Griffis, 1992), the desirability of the project (King and Mercer, 1985), and an honest self-evaluation of the ability and interest of the firm's personnel to complete the tasks required.

Often a firm wants to win the job is so that they can maintain a constant workload. Projects are the source for work as well as contributions to overhead costs. Managers must keep both work and income flowing into the company to maintain a viable business.

Consequently, a firm may proceed with the proposal development and submission, even though the job is not optimal.

The ups and downs of the marketplace create a business environment where it is difficult to maintain a constant workload and income. When there are fewer jobs to be had, a buyer's market, designers must accept jobs for decreased markups. When there is a proliferation of jobs, a seller's market, design firms can be more selective and negotiate higher profit margins. A strategy to minimize the influences of market highs and lows is to pursue long-term projects during a seller's market phase. These long-term profitable projects will carry the company through periods of fee deterioration. This strategy requires longer term planning on the part of the project managers.

The decision criterion, whether to submit or not submit a proposal, depends partly on the specific motivation for wanting to win the job. For example, if a firm decides they want to pursue prestigious jobs in order to change their image or build their portfolio, they will want to submit and win proposals for jobs with high prestige value. A knowledge of the likelihood of winning, will in all cases, support this decision making process. It is a futile endeavor to submit proposals for jobs where the firm has a low probability of winning. More often than not, the firm must compromise their profit margin in order to win such jobs. The Value-Bidding Model provides engineers with insight into the probability of winning and allows them to pursue jobs where they have greater leverage and a competitive advantage to substantiate their fee.

In this section, there is a shift from the concerns and utility of the owner, to the utility of the design firm. The decision metric here is whether submitting a proposal for a job is advantageous for the design firm. There are questions as to whether the design firm currently needs more work, whether the firm employees are qualified for the work, whether there is an attractive potential profit margin, whether the job will lead to other jobs with the owner, and whether there is a high probability of winning if the design firm submits a proposal. The aspects of the prospective job can be summarized as follows:

1. Resource capacity and need to work
    a. Job Volume, quantity of work
    b. Job Delivery, difficulty of delivery, i.e. technology requirements
2. Follow-up opportunities
    a. Potential for future work
    b. Owner's expectations (invitation to submit a proposal)
3. Prestige value of the job/ difficulty and challenge of the job
4. Potential profit
5. Probability of winning

7.2.1 Paranka Rating Methodology

First, the author recommends a rating system proposed by Stephen Paranka in his 1971 paper. This rating system provides a quick method of evaluating a prospective project. Though this method was developed for the manufacturing industry, this decision support system is applicable to the engineering design community as well.

The first step includes defining factors that influence the decision process and rating these factors according to importance. For example, a hypothetical firm rates these factors according to their current market status.

Factors	Rating according to importance of firm
Work Volume	13
Follow-up opportunities	20
Potential for future work	23
Prestige	8
Potential Profit	18
Probability of winning job	23
total	*100*

Table 7.1 Example Factors and Weights That are Important in the Decision Whether to Submit or Not Submit a Proposal

Next, each factor is rated according to the job's specifications. This second rating reflects the relative merit of each factor. For example, if the job is large or lengthy and will provide consistent work for a relatively long duration, the merit would be high. If it is a small job with a short duration, the merit would be low. For this analysis, Paranka recommends the following tabular format (Paranka, 1971). The first rating, (firm priority) is multiplied by the second rating (job merit) which results in a relative worth value for each factor:

		Job Merit Rating of			
Factors	Rating according to importance of firm	High (10)	Medium (5)	Low (0)	Total Value
Work Volume	13	10			130
Follow-up opportunities	20		5		100
Potential for future work	21	10			210
Prestige	8			0	0
Potential Profit	16		5		80
Probability of winning job	22		5		110
total	*100*				*630*

Highest possible rating	1000
Job rating: percent	63%

Figure 7.1 Rating Matrix for Paranka's Pre-Bid Analysis (Paranka, 1971)

The total value of the job is calculated by adding the individual worth values for each factor. The results can be utilized in a number of ways. First, depending on the criteria for choosing to submit a proposal, this method can be used with a minimum cutoff below which the jobs will not be considered. Second, this rating method can be used to compare numerous proposal opportunities. Decision makers could then choose to submit a proposal to the highest rated jobs. Paranka's method determines if the job is attractive to the design firm.

7.2.2 Value-Bidding Method

In conjunction with Paranka's pre-bid decision methodology, one could utilize the Value-Bidding Model to determine a preliminary probability of winning and use this information to decide whether to pursue a particular job. Paranka's model determines the job's attractiveness, and the Value-Bidding Model predicts the probability of winning. If the likelihood of winning is low, the design firm may not want to invest the resources to develop a proposal, even if the job is deemed attractive.

Due to limited resources, a detailed analysis, as presented in Chapters 5 and 6, is prohibitive for preliminary decisions. However, a more detailed study is a more accurate one. It is up to the design firm to decide the level of detail and specifics to apply at what phase in the proposal selection process. To simplify the analysis, we utilize the concept of an average competitor. In Chapter 6, section 3, the author outlines the methodology and issues regarding the development of an average competitor profile. Here, the author extends this idea to a more general case when the number of competitors is unknown. The general process by which one conducts a Value-Bidding pre-proposal analysis can be outlined as follows:

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1. Conjoint Study. If the firm has been using Value-Bidding, they have already conducted a conjoint study, and have data pertaining to the owner preferences, with which one can calibrate the model, (described in Chapter 4 and 5). Furthermore, one might be able to modify the utility values to reflect any unique knowledge regarding the current owner under study. If there is no conjoint study data pertaining to this type of owner, then the designer needs to start at the beginning and develop a conjoint study to capture the values of the owner.

2. Competitor Profiles. As was discussed in Chapter 6, a firm should gather data regarding competitors and compile and analyze this data in the aggregate to formulate average competitor profiles. The initial data collection effort is formidable; however, once the data is collected, the estimation of the average competitor is straightforward.

3. Probability of Winning. These average competitor profiles can be combined to develop the probability of winning over one average competitor using the following equation from Chapters 5 and 6.

$$(7.1) \quad P_i(win) = \sum_{\alpha=1}^{A} \sum_{\beta=1}^{B} \ldots \sum_{\zeta=1}^{Z} P_{i,(\alpha,\beta \ldots \zeta)}(win) * P(\alpha,\beta \ldots \zeta)$$

Recall that each competitor is defined by a set of attributes, α,β,...ζ, and $P_{i,(\alpha,\beta \ldots \zeta)}(win)$ is the probability of the ith profile winning given a competitor with attribute levels α, β, ... ζ. And $P(\alpha,\beta \ldots \zeta)$ is the probability of profile existence, which is derived from the aggregate histograms of the known competitor attributes. (See Chapter 6, section 3 for details.)

4. Gates' Equation. As was discussed in Chapter 5, the Gates' equation (equation 5.13), from competitive bidding theory, can be used to combine the probabilities of winning over different competitors. Given n average competitors, the Gates' equation becomes:

$$(7.2) \quad P_n(win) = \frac{1}{1 + n\left(\frac{1 - P_i(win)}{P_i(win)}\right)}$$

5. Histogram: Number of Competitors. If the number of competitors is unknown, it should be treated as a random variable, whose probability distribution can be derived from historical data. From past competitive proposal processes, the design firm should record the number of competitors. This information can be accumulated into a histogram:

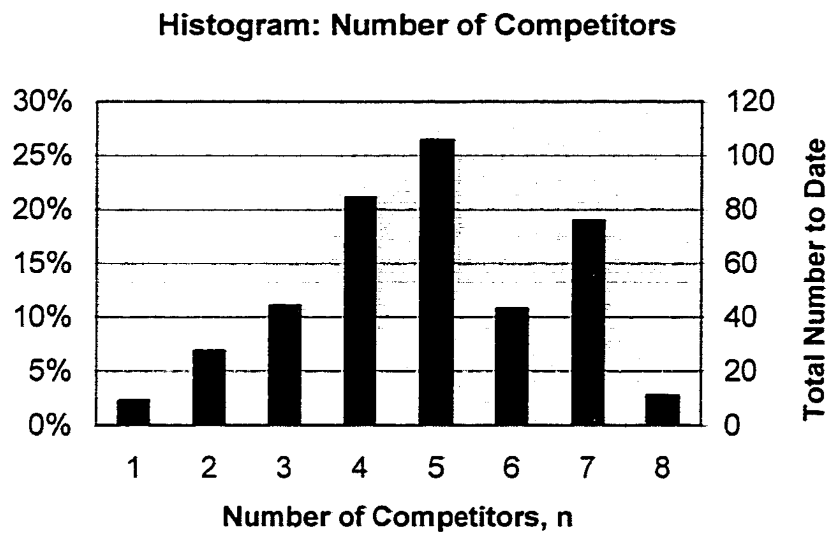


Figure 7.2 Histogram: Number of Competitors

Define g(n) as the function that describes the probability of n competitors. For example, given the above histogram, g(1) = 2%, and g(2) = 7%.

6. Average Probability of Winning with Unknown Number of Competitors. Given the average probability of winning and the probability function for expected number of competitors, the author presents the following equation for the general average probability of winning:

(7.3a) $$P_{AVE}(win) = \sum_{n=1}^{\infty} g(n) * P_n(win)$$

or

(7.3b) $$P_{AVE}(win) = \sum_{n=1}^{\infty} \frac{g(n)}{1 + n\left(\frac{1 - P_i(win)}{P_i(win)}\right)}$$

where $P_i(win)$ is defined in step 3 above (as well as in Chapters 5 and 6).

There is a possibility that this model can become too generalized. and that average probabilities do not differ between projects. Therefore, to preserve a useful model, one must strive to model the specific job under consideration. Many aspects of the Value-Bidding Model are designed for customization. Often, designers know the owner and potential competitors for a job. and they should be encouraged to incorporate this knowledge into the Value-Bidding Model. For example, one could focus the study on attributes that are of particular importance to the owner. Often, the RFP provides information as to what the owners are looking for. Past experience with an owner, post-selection or post-job interviews will also provide information in this regard. Furthermore, when modeling the number of competitors and the average competitors, one must attempt to only use past projects that have similarities to the one under current analysis. The calculations could be automated, which would facilitate customization of the Value-Bidding Model (See Appendix D). Although many inputs of the Value-Bidding Model are based on historical data, there is room for interpretation. The user is encouraged to calibrate and modify the model to reflect any specific knowledge that may be available to the user. In this regard, the Value-Bidding Model will reflect the intuitive and personal knowledge project managers have regarding the owner, competitors and the market. For example, if it is known that a competitor is considering submitting a proposal for a specific job, one might consider including the known competitor's profile into the model to account for this more accurate knowledge. These issues will be illustrated in the case study discussed in Chapter 9.

The decision criteria for the Value-Bidding method can be modified by experience as well as urgency to win future work. The author proposes that given an attractive prospective job, if the probability is greater than average, the design firm should proceed with the proposal or at least with a more detailed analysis of the owner and competition. If the design firm has less than an average chance of winning based on the general average probability of winning, the author recommends forgoing this particular job and finding jobs where the risk is less. Given n known competitors, the decision rule may then be stated as:

If $P_{ave}(win) = \frac{1}{n} < P_o(win)$ continue analysis

If otherwise, forgo project unless there are other reasons to submit a proposal.

Figure 7.3 Decision Rule to Submit a Proposal or Not Submit a Proposal with Known Number of Competitors

If the number of competitors, n, is unknown, the expected value of n can be used:

$$(7.4) \qquad E(n) = \sum_{n=1}^{\infty} n * P(n)$$

where P(n) can be determined from a relative frequency histogram of past projects. Then the decision rule becomes

If $P_{ave}(win) = \frac{1}{E(n)} < P_n(win)$ continue analysis
If otherwise, forgo project unless there are other reasons to submit a proposal.

Figure 7.4 Decision Rule to Submit a Proposal or Not Submit a Proposal with Unknown Number of Competitors

The cut-off point may vary per industry and this provides a topic of future research involving the Value-Bidding concept and models.

7.3 Quality-Based Selection (Without Fee Proposal)

Quality-based selection can refer to a selection process based on qualifications with or without a fee proposal. If the RFP[1] specifies selection criteria devoid of a fee proposal, than it is a pure value competition. Value-Bidding was designed for this type of problem. The main goal then is to optimize the probability of winning given the attributes that the owner deems valuable. Recall from Chapter 5 that the probability of winning is based on the attribute levels of a design firm, as well as the attribute levels of a competitor.

[1] Request for Proposal

7.3.1 Proposal/Presentation Review

In this section, the objective is to maximize the probability of winning. Generally, the goal to win the job is qualified with some limitations. For example, a firm does not want to present a proposal it cannot commit to. This practice is illegal and could have disastrous results. The result of a Value-Bidding analysis is to provide the design engineer with a tool to optimize their proposal and maximize their probability of winning.

$$(7.5) \qquad \max\left[P\,(win)\right] \qquad \text{or} \qquad \max\,[U_o(\alpha,\beta,\ldots\zeta)]$$

with the constraint that the design firm can meet the proposal promises. In order to maximize the probability of winning, we must examine the development of this probability. Figure 5.4 shows the data accumulation paths for developing a conjoint study based probability of winning. There are three key steps.

1) Determine the influential attributes of design services

2) Conduct a conjoint (CBC) study of owners to develop attribute level utilities

3) Develop competitor profiles

The first step in the process of conducting a Value-Bidding analysis is one of the most critical. One must determine the attributes with which the owners will judge the relative value of the services rendered and with which the firm will be compared to it's competitors. It is suggested in Chapter 5 that a preliminary study be conducted to survey owners to determine what the most important attributes of the design services are and what they base their decisions on. Sometimes, this type of information can also be found in the RFPs themselves, as well as post selection and post job interviews and surveys. The choice of attributes influences the accuracy and validity of the estimated probability of winning in the Value-Bidding analysis. Just as the foundation of a building determines the fundamental structural integrity of the structure, so to does the choice of attributes dictate the validity of the Value-Bidding Model.

Conjoint studies are common in the marketing research community. Wittink and Cattin (1989) estimated that about 400 commercial applications of conjoint analysis were conducted per year in the 1980s. Conjoint studies are standard practice for many industries, but have not been used to any extent in the civil engineering industry (Gelb,1998). With this well-developed and tested approach, one can estimate the owner's utility for any number of design service attributes and levels. Utility weights provide clues as to what aspects of design services, (or any other project or service) owners value. Market simulators, like those developed by Sawtooth Software (Orme, 2000), estimate probabilities of winning based on these utility values. Therefore, to increase the probability of winning, one should to match the attribute levels with the highest utility values.

For example, Table 5.1 presents some utility values for a number of possible design attributes. The table is repeated here for convenience.

Attribute	Level	Utility (weight)
Services offered in-house		
Program management	have / do not have	42 / -42
Construction	have / do not have	14 / -14
Equity capital	have / do not have	12 / -12
Firm size		
Total size (partnerships and subsidiaries	International	12
	National	-2
	Local	-10
Branch size (proposing for job)	Corporate Headquarters	10
	Regional Branch Office	-3
	Project Office	-7
Personal relationship between designer and owner		
	Worked several jobs, positive experience	65
	Worked one job, positive experience	35
	Worked no previous jobs together	-9
	Worked one job, negative experience	-23
	Worked several jobs, negative experience	-68

Table 7.2 Attribute, Levels and Utilities for Example Analysis

The relative importance of each attribute can be calculated using the range of the utility values. (Orme, 1999)

Attribute	Range	Percent Importance
Services offered in-house		
Program management	84	27%
Construction	28	9%
Equity capital	24	8%
Firm size		
Total size (partnerships and subsidiaries	22	7%
Branch size (proposing for job)	17	6%
Personal relationship between designer and owner	133	43%
Sum total	308	

Table 7.3 The Utility Range and Percentages for Example Attributes

In the above example, the attribute -- personal relationship between designer and owner -- is the most influential in the owner's selection process. This information provides the design engineers with the knowledge that past experience with the design weighs heavily on the owner's selection decision. Some attention should be placed on this attribute. For instance, it is a wise investment to assure a positive experience on a current job, for higher utility points for any future jobs with the owner. If the designer has not worked with a particular owner, the importance weights tell the designer a number of things. First, the utility for other attributes must counterbalance the important and low utility rating for not having previous experience with the owner. Second, the owner values repeat business with the designer whom they have had a positive experience with. This knowledge could set into motion other strategies in an attempt to increase the utility for this attribute, and consequently, the probability of winning. For example, if a design firm has not worked with the owner previously, but knows that the owner values positive repeat business, the design firm could approach past clients with whom they have a good rapport, and put these past clients in touch with the owner the designer is currently soliciting work from. A personal recommendation from an owner who has worked repeatedly with the design firm, might provide enough evidence for the current owner to regard this new design firm in a more positive and valuable light. Consequently, the utility weights from the conjoint study provide valuable evidence for the owner's priorities and values. This insight, combined with the knowledge of competitors, can increase the likelihood of success.

Lastly, the formation of competitors' profiles is a critical element of the probability of winning estimation calculation. Since the design firm is being compared directly with competitors, the differences between the competitors' profiles and the designer's are paramount. Using the Value-Bidding Model, one can quantify as well as qualify the competitive advantage the design firm has over its competitors. If a firm does not have a competitive advantage for at least one sector or set of owners, there is a need for redirection and repositioning of the firm. Though the distinction might not be great, the proposal should document and emphasize the reasons why the design firm is the best firm for the job. The conjoint analysis and subsequent Value-Bidding comparisons will support the development of winning proposals. Though the numbers tell a story, the interpretation of those numbers and the actions brought about by the analytics are the real metal of a model.

7.3.2 Negotiations

Value-Bidding is particularly useful to an engineer during the negotiation phase of a quality-based selection process. The design fee and contract details are defined in this phase, and the results of the Value-Bidding calculations will determine and support the design fee estimation. Negotiating the design fee has become an art in this highly competitive environment, and there is much to be said for interpersonal relationships and salesmanship, but the Value-Bidding results will support the arguments surrounding the design fee proposal and theoretically, should make the sale easier.

A client or customer is generally willing to spend more money on a product or service they think is of higher quality or worth more than the competition's product or services. In general, consumers are under the impression, even though this is not always true, that a higher price reflects a better quality product or service, (Nagle and Holden, 1995). Consequently, since the conjoint study enables the users to develop a proposal based on the owner's perception of quality, a reasonable fee should be easier to negotiate based solely on the fact that the owner is under the impression they are going to receive high quality service for a competitive price.

Furthermore, if the fee is included as an attribute in the conjoint analysis, one can determine what owners are willing to pay for. This calculation is analogous to the estimation of the probability of winning; however, it is now referred to as the likelihood of purchase. The designer's goal at this stage is to negotiate the highest fee possible – i.e., maximize profit. Using the Value-Bidding analysis, the potential profiles include the design firm's attributes while the fee varies. If the fee is an attribute of the design service, and is designated as ϕ, then the likelihood of purchase can be written as:

(7.6) $$P(U_\phi) = \frac{e^{U_\phi}}{\sum_{\phi=1}^{\Phi} e^{U_\phi}}$$

where U_ϕ is the utility of the design firm given the fee level ϕ. This equation can be used to determine the likelihood of purchase or each feel level.

7.4 Quality-Based Selection (With Fee Proposal)

7.4.1 Proposal/Presentation Review

Unlike most of the other qualitative factors addressed in this thesis, the variability of price for service can be modeled in much greater detail. As discussed in Chapter 3, the estimate for a competitors fee proposal can be modeled as the distribution of the fee (bid) to cost ratio using historical data.

Adding the distribution of the fee into the equation makes the Value-Bidding problem more complicated. Rarely are design firms chosen from a pure competitive bidding situation. Therefore, the selection is based on the perceived value weighed by the proposal price, (Phipps, 2000). In a quality-based selection process, a design firm attempts to maximize the perceived quality or value of their proposal in proportion to the proposed fee.

$$\max[U(f)] \qquad (7.7)$$

where $U(f)$ is the total utility of the owner, and f is the proposed fee. Note that $U(f)$ increases as f decreases. But, the design engineer wants to maintain a profitable business. We then can quantify how low a fee should be to still get the job.

This is the heart of the Value-Bidding Model. There are several criteria by which one can develop the optimal utility and fee. One goal might be to maximize the probability of winning while simultaneously minimize the amount of money left on the table. As a case in point, Alan Phipps, the western regional director of Figg Bridge Engineers, Denver, reported on the procurement of a design/build team by the Maine DOT in ASCE's *Civil Engineering Magazine*, (Phipps, 2000). The Maine DOT chose the proposal carrying the lowest price per technical score point, e.g. quality-based selection in relation to proposed fee; however, the winning team, Flatiron-Figg Joint Venture, left \$15.7 million on the table. In other words, they could have proposed a fee that was \$15.7 million more than they did and still have won the contract. Therefore, the objective of this model is to increase the chances of winning the job, while minimizing the foregone profit. There are two main approaches one can take, given the information available from the Value-Bidding Model:

1. Maximize the utility to fee ratio and minimize the money left on the table
2. Develop the probability of winning over competitor with various fees and balance the lower probability of winning with the higher profit.

The complexity arises due to the fact that the probability distribution of price is continuous while fee levels are discrete in conjoint analysis. Recall that the attributes are designated as $\alpha, \beta, \ldots \zeta$. The utility function, $U(\alpha, \beta, \ldots \zeta)$, can be developed from the part worths (attribute level utilities) estimated from the conjoint study. The utility function is defined in Chapter 4, equation 4.1b, and is repeated here for convenience:

(7.8) $$U(\alpha, \beta \ldots \zeta) = u(\alpha) + u(\beta) + \ldots + u(\zeta)$$

where u() is the part worth for attributes α, β, and so forth for all the attributes and $U(\alpha, \beta, \ldots \zeta)$ is the total profile utility.

As discussed in Chapters 4, 5 and 6, attributes are dealt with in discrete levels. For example, if fee is an attribute, its levels may be 5%, 8% and 10%. The fee could be measured in total dollars, (1.5 million, 3 million and 5 million), in general terms, (lowest, average, and high), or in percentage terms, percentage of construction costs (fixed fee), percentage of design costs (cost plus), or percentage of total project costs (design/build, fixed fee).[2] If the attribute: fee is notated as ϕ, with levels, 1–A, a Value-Bidding metric to maximize the probability of winning can be written as the utility function:

(7.9) $$\max[U(\phi,\alpha,\beta,...\zeta)]$$

In this computation, we seek the attribute levels, attribute α with levels (1–A), β with (1–B), etc., which maximize the utility function in proportion to the proposal price, ϕ.

Part two involves the comparison of competitors to the designer utilizing the Value-Bidding Model. If the fee levels are presented in percentages, we can compare the utility to fee ratios directly. However, if the fees are presented in dollar amounts, we must normalize the price levels. In competitive bidding theory, researchers chose to normalize the bids with the contractor's estimated cost. We adopt this practice for the design firm as well. If the fee is based on the cost of design, we can divide all of the fees by the designer's estimated cost for the job. If the fee is based on a percent of construction costs, the fee can be divided by this estimate. And finally, if the design is part of a larger

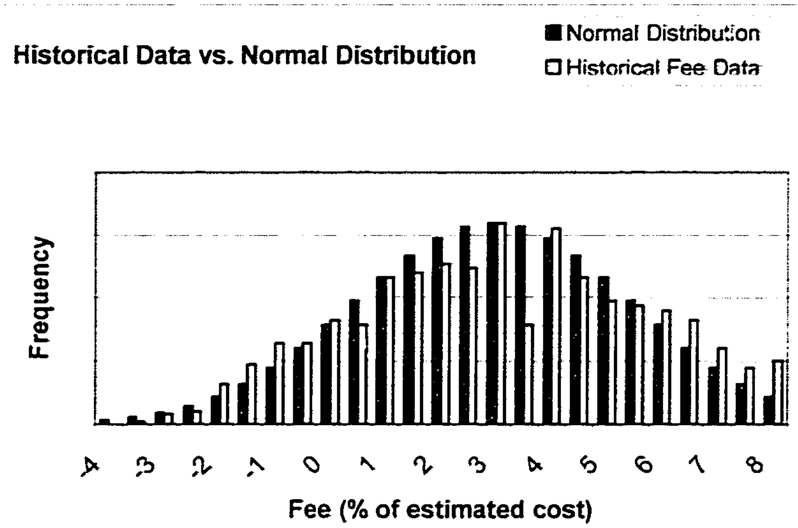
[2] Since design firms would not conduct a conjoint study for each individual proposal, the model users would want to develop more general attribute levels so that their results can be used for many proposals in a given industry or area.

design/build project, the design fee is a percentage of the total project cost, and the proposal fee is a combination of the design and construction costs, plus a markup.

Based on historical and public data, the designer has less than perfect information about the known competitors. For example, as in the competitive bidding methodology, a designer can develop a probability distribution of the competitor's fee (Section 3.2). The normalized competitor's fee, represented as f_c, has a probability distribution of, $g(f_c)$, which is estimated from the histogram of past fee proposals. For example, if the historical data approximates a normal distribution, the competitor's fee could be estimated by:

(7.10) $$g_c(f_c) = \frac{1}{\sqrt{2\pi\sigma^2_{f_c}}} e^{\frac{-(f_c - \mu_{f_c}^2)}{2\sigma^2_{f_c}}}$$

The author recommends that the modeler use the percent of total project cost for the sake of generality. For other types of contracts, the fee levels can be derived from total project costs used in the conjoint study.



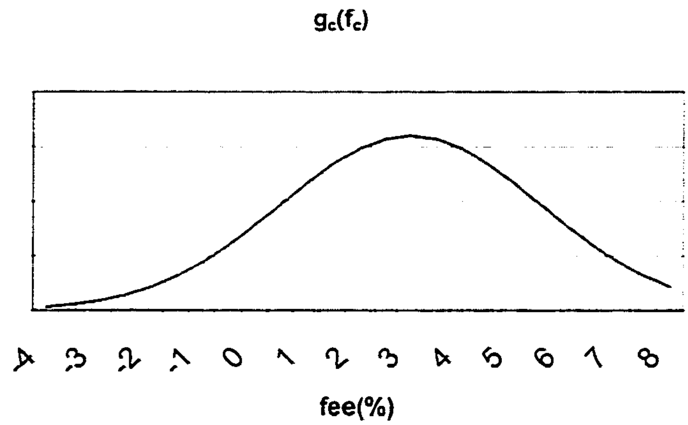


Figure 7.5 Probability Distribution of Competitor's Fee

From the probability distribution $g_c(f_c)$, we can estimate the probability of the competitor's fee proposal being greater than any given level, f.

$$(7.11) \qquad P(attribute\_\phi \geq f) = \int_f^x g_c(f_c)\,df_c$$

This can be incorporated into the probability of profile existence for the competitor. Recall from Chapter 6,

(7.12)

$$P(profile_j exists) = P(attribute\_\alpha = level_j) * P(attribute\_\beta = level_j) * ... * P(attribute\_\zeta = level_j)$$

Incorporating the special attribute fee, ϕ, we have the probability of profile existence:

(7.13)

$$P_c(\alpha, \beta, ... \phi) = P(profile_j exists) = P(attribute\_\alpha = level_j) * P(attribute\_\beta = level_j) * ... * P(attribute\_\phi > f_j)$$

where the subscript j signifies the attribute level associated with the jth possible profile for the competitor, c. See Chapter 5 for the process of incorporating this probability of profile existence into the estimation of probability of winning.

This analysis results in the ability to estimate the probability of winning given various fee levels, P(win, ϕ). These calculations are analogous to the competitive bidding models discussed in Chapter 3, for estimating likely competitor bids. However, we must model proposal price in discrete levels, as opposed to competitive bidding theory's continuous functions. Therefore, we define the probability of a competitor's fee being in a given range as:

$$(7.14) \qquad P(attribute\_\phi = level\_f) = \int_{level\_f} g_c(f_c)df_c$$

Comparisons with competitors are not limited to the estimation of the probability of winning. We can also develop a utility to fee ratio for competitors, $U_c(\alpha,\beta,...\phi)$, and each of these ratios have an associated probability of profile existence $P_c(\alpha,\beta,...\phi)$. We can use this information to minimize the money left on the table. Consider the following analysis.

$$(7.15) \quad Max[U_o(\alpha,\beta,...,\phi)] \ \& \ Max[\phi]$$

while providing that

$$(7.16) \quad \frac{U_o}{\phi} \geq E\left[\frac{U_k}{\phi}\right]$$

if

$$(7.17) \quad E\left[\frac{U_k}{\phi}\right] = \sum_{\alpha=1}^{A}\sum_{\beta=1}^{B}...\sum_{\phi=1}^{\Phi}\frac{U_k(\alpha,\beta,...\phi)}{\phi} * P_k(\alpha,\beta,...\phi)$$

for all competitors k.

This is an iterative process. In other words, the objective is to find the highest fee and utility that also allows the designer's utility-to-fee ratio to remain higher than the competitors' utility-to-fee ratios. In this way, we can minimize the money left on the table, but still assure a reasonable chance of winning. This analysis can be doubled checked using the calculation of the probability of winning given the optimal fee calculated from the utility to fee ratio method above.

7.4.2 Negotiations

Since, in this case, the fee proposal is addressed in the previous stage, there may be limited negotiation regarding the fee at this time. However, if there is still some negotiation, the Value-Bidding analyses give the designer concrete analytics to substantiate their fee. They might not want to disclose the method of analysis, but one can argue the quality that is presented to the owner and negotiate with the valuable attributes of the service in mind. For instance, if the owner wishes to decrease the fee, the designer can offer to decrease the services they are offering. Thus, the value presented in the services, matches the fee requested. (Nagle and Holden, 1995)

7.5 Enter New Territory

7.5.1 Discussion

There are two types of territories a design firm may wish to enter. The first is geographic territory. Perhaps the construction market is growing in a neighboring state, or the company is expanding and needs to expand into other geographic territories to accommodate the need to work. The second territory type is technical. A firm may deem it valuable to add new technical expertise to the design services offered in-house. This type of expansion might prompt the pursuit of jobs that require the new technical expertise. In both cases, the owners will generally be unfamiliar with the design firm, as will the design firm with the owners. Value-Bidding is poised as a good tool to acquire knowledge of a new territory. The conjoint analysis captures the owner's value structure, and the process of developing competitor profiles enables the designer to determine the likelihood of success in the new territory. The Value-Bidding analysis has the potential to save a design firm from pursuing entry into a hostile territory where it would be very difficult for them to make a profit, obtain work, etc. Secondly, Value-Bidding can potentially guide a design firm to acquire a new service in-house based on the results of conjoint studies.

The proposal objective of entering a new territory is a special case of the objective to win the job. When entering a new territory, a firm is ready to compromise their profit margin to gain entry. After they have established their resume in the new territory, they have a better footing from which to pursue more profitable work. In this section we discuss ways in which the Value-Bidding analysis, presented in Chapters 5, and 6 can support a firm's attempt to enter new territory. For example, a firm might pursue a competitive proposal submission with a low probability of winning to attempt to break into a new market. Value-Bidding make some decision metrics available to support such business decisions.

7.5.2 Bid/No Bid Decision

Value-Bidding is particularly useful in the case of an attempt to enter a relatively new territory. It is an approach to study the unknown. One should proceed through the entire Value-Bidding process to benefit from the analysis. Once the attributes are determined, and the conjoint study conducted, the utility weights can be good indicators of a prudent step forward. For example, it might be very important to determine how much emphasis (importance) the owner places on having worked with the client before. If the importance is estimated to be greater than 50%, that it is unadvisable to submit a proposal unless there is evidence that the owner is looking for a new design firm. Since the utilities are additive (equation 4.1), it is unlikely that other positive attribute utilizes can outweigh a negative attribute with importance of over 50%. In this case, the design firm should seek a job where it is known that the owner is looking to work with a new firm. The method of developing attribute importance levels is described in Chapter 7, Section 3.

The Value-Bidding methodology can determine if your firm has enough positive utility points with the owner to outweigh any negative perceptions they might have toward your proposal. Preliminary investigation on the part of project managers can save a design firm the expense of submitting proposals for jobs they are not likely to win.

References

Gelb, M Gabriel, (1988) "Conjoint analysis Helps Explain the Bid Process," Marketing News, American Marketing Association, Vol. 22, No. 6, March 14, 1988, pg. 1 and 31.

Griffis, F.H.(Bud), (1992) "Bidding Strategy: Winning Over Key Competitors", Journal of Construction Engineering and Management, ASCE, Vol. 118, No. 1, March 1992, pg. 151-165.

King, Malcom, and Alan Mercer, (1985), "Problems in Determining Bidding Strategies," The Journal of the Operations Research Society, Vol. 36, No. 10, Nov. 1985, pg. 915-923.

Nagle, Thomas, T. and Reed K. Holden, (1995) The Strategy and Tactics of Pricing, A Guide to Profitable Decision Making, Second Edition, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1995.

Orme, Bryan, Editor, (2000) The Sawtooth Software Market Simulator, Sawtooth Software, Inc., Sequim, WA, http://www.sawtoothsoftware.com

Orme, Bryan, Editor, (1999) CBC User Manual, Version 2.0, Sawtooth Software, Inc., Sequim, WA, http://www.sawtoothsoftware.com

Paranka, Stephen, (1971) "Competitive Bidding Strategy, A Procedure for Pre-Bid Analysis," Business Horizons, Vol. 14, June 1971, pg. 39-43.

Phipps, Alan R., (2000) "Box Girder Balancing Act" Civil Engineering, ASCE, March 2000, pg. 33-39.

Wittink, Dick R., and Philippe Cattin (1989), "Commercial Use of Conjoint analysis: An Update", Journal of Marketing, Vol. 53, July 1989, pg. 91-96.

Chapter 8

Proposal Goal: Maximize Profit

"There are many reasons for desiring to be the successful bidder. In its broadest sense, profit is probably the greatest motivating factor."

- Marvin Gates, President, Construction Estimating, Inc., 1967

8.1 Introduction

The objective discussed in this chapter is to maximize the profitability of the company. This objective is sought by only submitting proposals to potentially profitable (and winnable) projects, optimizing the proposals, and supporting the negotiations by substantiating the value of the services offered. The Value-Bidding Model was developed with this objective in mind. The conjoint analysis identifies the aspects of the design services that the owner values. This assists the design firm in submitting a higher percentage of winning proposals, and avoiding requests for proposals (RFPs) where they have a low probability of winning. Value-Bidding can find the optimal set of attributes for a design service, which supports the proposal preparation and oral presentation delivery. Furthermore, it gives the design firm the tools to justify profitable fees during the negotiation process.

8.2 Submit/Do Not Submit Proposal Decision

8.2.1 The Decision

Preparing and submitting a proposal in response to a request for proposals (RFP) can be an expensive task (Phipps, 2000), and is not always reimbursable from the owner, particularly if the firm does not win the contract. Consequently, it is important to estimate the probability of winning the job even before preparing a concept or proposal for a client. There has been limited research into a methodology to support the decision to prepare a proposal, and what models that do exist, are geared toward construction bid/no bid decisions. (Paranka, 1971) Therefore, the following model is presented to address the first decision in the design engineering procurement process: should we, or should we not answer the RFP?

Value-Bidding supports the decision by estimating the probability of winning given the known set of attributes and owners' preferences. As discussed in Chapter 6, the attributes of competitors are accumulated from historical data (past proposal results), public information (i.e., firm size and specialty areas), along with personal knowledge of the firm (through industry connections). The owners' preferences can be acquired through conjoint studies, the RFP, as well as personal knowledge.

This methodology can determine if the design firm:

1. Is in the right market position to win the contract in question.

2. Has the correct specialty mix to address the owners' needs and concerns

3. Has the personnel with the expertise to support a proposal

Furthermore, this methodology can determine if your firm has enough positive utility points with the owner to outweigh any negative perceptions they might have toward your proposal. Preliminary investigation on the part of project managers can save a design firm the expense of submitting proposals for jobs they are not likely to win.

8.2.2 Decision Criterion

To develop these criteria, we look to opportunity cost theory. An opportunity cost is an income or loss forgone when a choice is made. If the design firm chooses to not submit the proposal, they forgo the potential income and profit that they might have received if they had won the contract. Consequently, a design firm would want to submit a proposal if the *Cost of **not** submitting a proposal outweighs the cost of generating proposal.* In the simplest case, the cost of not submitting a proposal is equal to the sum of the profit if they win and zero if they lose. This is the expected profit, by definition. E(P) = $P(win)*(F_e - C_e)$, where F_e is the estimated fee collected for the project, and C_e is the estimated cost for the project.

However, it would not be financially sound to submit a proposal with the chance of only recovering costs, i.e. break even. We need to incorporate the minimum attractive rate of return (MARR) into this decision criterion. The MARR is equal to the rate of return that one may obtain in another venture with the same risk, (Griffis and Farr, 2000). A project is economically attractive if the expected return is greater than or equal to the MARR. Potential income can be weighed against lost opportunities to support any business decision. If the estimated cost for submitting a proposal is designated as C_{pe}, the decision criteria, to submit or not submit a proposal can be expressed as:

$$P(win) * (F_e - C_e) \geq (1 + MARR)C_{pe} \quad (8.1)$$

The estimated fee and costs can be determined from the historical data on projects with similar characteristics to the one being considered. In general, the MARR is defined by the cost of capital, the interest rates for borrowing and lending, accounting for the risk associated with the loan or investment.

The key unknown in this equation is the probability of winning, which we can determine with the Value-Bidding Model (Chapter 5). Other opportunity costs may be included in the model as well. For example, the lost opportunity costs can include other investments the design firm might make, such as the development of other proposals with higher changes of winning.

8.3 Quality-Based Selection Without Fee

8.3.1 Proposal/Presentation Review

The designer's basic assumption for quality-based selection is that the higher quality can reflect a higher fee, and therefore larger profit margin. This may not always be the case. For example, a public project may have a fixed budget for design services. The procurement officials may not have the power to secure more funding. Therefore, the project has a capped fee allocation. When this is the case, value-pricing theory suggests that the designer offer a limited version of the services to reflect the reduction of fee. (Stasiowski, 1993) Or, in other cases, the owner may be looking for the least expensive way to get the job done, and does not value quality as highly as saving money. However, for this discussion, the author assumes that these cases are more the exception than the rule.

This analysis is based on the assumption that quality reflects value, and higher value results in higher fee. Quality => Value => Profit. In the selection, the proposal process without a fee proposal is addressed, and in order to obtain our goal for maximizing profit, we should then maximize value. In the Value-Bidding notation, the value is reflected in the utility. The optimization metric for this section is:

(8.2) $$\text{Max}\ [U]$$

The utility, U, is the sum of the part-worths estimated via the conjoint analysis described in Chapters 4, 5 and 6. Recall that the utility is the summation of the owners' utilities for each attribute in the profile. If the attributes are designated at $\alpha, \beta, \ldots \zeta$, then the maximization function is:

$$\max[U(\alpha, \beta, \ldots \zeta)] = \max[u(\alpha)] + \max[u(\beta)] + \ldots + \max[u(\zeta)] \tag{8.3}$$

To maximize the attribute utilities, a design firm should analyze and maximize each attribute in turn. For example, consider the following attribute and example levels and utilities.

Attribute	Level	Utility (weight)
Personal relationship between designer and owner	Worked several jobs, positive experience	65
	Worked one job, positive experience	35
	Worked no previous jobs together	-9
	Worked one job, negative experience	-23
	Worked several jobs, negative experience	-68

Table 8.1 Example Attribute, Levels and Utilities for Max Utility Analysis.

From previous discussions, Chapter 7 Section 3.1, it was determined that this attribute had a relative importance of 43%. Consequently, this is a very important attribute and should be weighted heavily in the proposal development. The design firm should endeavor to increase the owners' positive weight for this attribute. For instance, there are three main cases to consider. First, to maximize the utility of this attribute, a design firm must work multiple jobs for an owner, which results in a positive owner response and opinion of the firm. If this is the case, then the designer has maximized this attribute utility and should concentrate on other attributes. Second, if the design firm had not worked with the owner previously, they should endeavor to convince the owner that others, with whom they have worked extensively, have had positive experiences. Or, a designer can partner with, or hire as a subconsultant, a design engineer with whom the owner has worked previously; one the owner respects and feels comfortable with. Third, the design firm may have worked with an owner, but the owner had a negative impression of the firm. If this is the case, it is then imperative that the owner feels that a change has been made, either in management or in personnel, with whom they might have collided. For this attribute, the third case is the worst-case scenario, and the design firm must repair their image in the eyes of the owner.

Similar analysis should be made for all of the attributes, and an attempt to maximize the owners' utility should be made in each case. The result of this investigation will be a proposal and potential oral presentation that will show the design firm in the best light that reflects the owners' priorities.

The goal of the engineering designer's proposal is to maximize the owners' utility function. Not only will this maximize the potential for profit, but it will also maximize the probability of winning:

(8.4) $$\max\left[P_0(win)\right] = \frac{e^{\max[U_0]}}{\sum_{j=1}^{J} e^{[U_j]}}$$

Consequently, the engineering design firm will not only maximize their profit, but they will also increase their chance of winning the job.

8.3.2 Negotiations

As discussed in Chapter 7, the Value-Bidding analysis can give a designer insight into how much owners are willing to pay for services. Consider the assumption from the previous section: high value equals profitability. The objective then is to determine the fee that matches the owners' perception of value.

This optimization metric can be based on the classical competitive bidding definition of profit:

(8.5) $$\text{Profit} = P(win) * (F_e - C_e)$$

where F_e is the estimated fee, C_e is the estimated project cost, and the P(win) is the probability of winning. In competitive bidding theory, the probability of winning, P(win) is based on a fee comparison with competitors' bids. However, in most design service procurement processes, the owner creates a short list in the proposal/presentation stage. The first firm on this list is approached first to negotiate a contract. Therefore, in the analysis for the negotiation stage, the probability of winning over competitors should be replaced by the likelihood of purchase developed in Chapter 7 Section 3.2.

Recall that the likelihood of purchase is analogous to the estimation of the probability of winning. During the negotiations, the potential profiles include the design firm's attributes while generally only the fee varies. If the fee is an attribute of the design service, and is designated as ϕ, then the likelihood of purchase can be written as:

(8.6) $$P(U_\phi) = \frac{e^{U\phi}}{\sum_{\phi=1}^{\Phi} e^{U\phi}}$$

where U_ϕ is the utility of the design firm given the fee level ϕ. This equation can be used to determine the fee the owner is willing to pay, given the current attribute levels presented by the design firm.

Using the likelihood of purchase assumption, the estimated profit becomes:

(8.7) $$\text{E[Profit]} = P(U_\phi)*[F_e(\phi) - C_e] = \frac{e^{U\phi}}{1+e^{U\phi}}*[F_e(\phi) - C_e]$$

The attribute fee, ϕ, and the proposed project fee, F_e, both represent fee amount, but will often be quantified differently. For example, the attribute fee, ϕ, is a general term from the conjoint study and may often be specified as the percent of total cost. Whereas the fee estimate, F_e, is a specific dollar value, and specific to the project. The two can be related and therefore the proposed fee estimate, $F_e(\phi)$ is presented as a function of the attribute level, ϕ.

The objective in negotiations then, is to maximize the profit based on the value presented to the owner and what the owner is willing to pay for that value:

(8.8) Max [E[Profit]] $= \max\left\{\frac{e^{U\phi}}{1+e^{U\phi}} * [F_e(\phi) - C_e]\right\}$

The objectives are straightforward and logical; maximize the fee while minimizing the cost. However, this equation is based on the conjoint analysis presented earlier, and therefore is a reflection of the owners' value structure and their willingness to pay.

8.4 Quality-Based Selection With Fee

8.4.1 Proposal/Presentation Review

As was discussed in the previous section, the classical equation for profit from competitive bidding theory is:

(8.9) Profit $= P(win) * (F_e - C_e)$

where F_e is the estimated fee, C_e is the estimated project cost, and the P(win) is the probability of winning. As suggested earlier, the probability of winning can be determined using the Value-Bidding Model presented in Chapter 5. Recall the process is as follows:

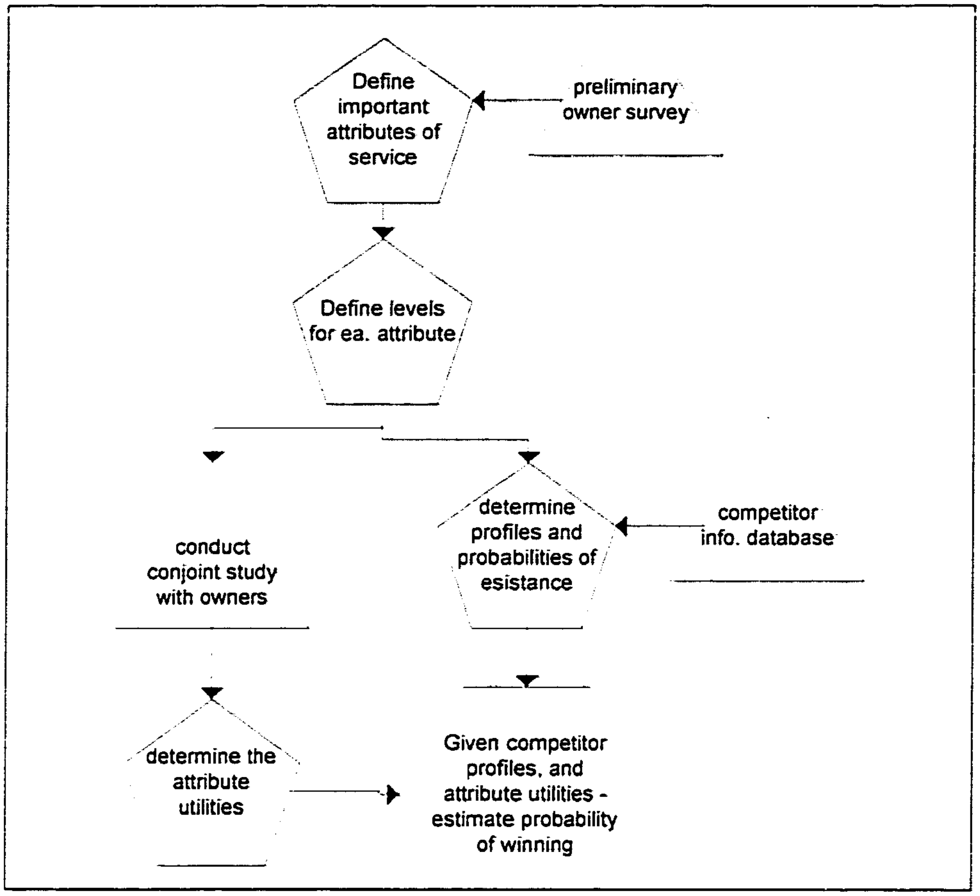


Figure 8.1 Inputs to Estimate the Probability of Winning

In this section, the author addressed the case when the fee is included as an important attribute in the proposal stage. Recall from Chapter 7, Section 4, the author discussed the development of the probability of the competitor's fee being larger than the designer's. The historical data can be collected into histograms and a probability distribution, $g(f_c)$, can be determined. For example, the normal distribution is a commonly used estimate:

8.10 $$g_c(f_c) = \frac{1}{\sqrt{2\pi\sigma_{f_c}^2}} e^{\frac{-(f_c - \mu_{f_c}{}^2)}{2\sigma_{f_c}^2}}$$

Using the probability distribution, $g_c(f_c)$, we can estimate the probability of the competitor's fee proposal being within a certain range or conjoint level$_f$.

8.11 $$P(attribute\_\phi = level\_f) = \int_{level\_f} g_c(f_c)df_c$$

In the Value-Bidding analysis, this probability is then incorporated into the probability of profile existence. Given that attribute fee is designated as ϕ, the probability of profile existence can be written as:

8.12

$$P_c(\alpha,\beta....\phi) = P(profile_j exists) = P(attribute\_\alpha = level_j) * P(attribute\_\beta = level_j) * ... * P(attribute\_\phi = f_j)$$

This in turn is used to estimate the probability of winning:

8.13 $$P_{o,t}(win) = \sum_{\alpha=1}^{A}\sum_{\beta=1}^{B}...\sum_{\phi=1}^{\Phi} P_{o,t,(\alpha,\beta...\phi)}(win) * P_t(\alpha,\beta...\phi)$$

and

8.14 $$P_o(win) = \frac{1}{1+\sum_{t=1}^{n}\frac{1-P_{o,t}(win)}{P_{o,t}(win)}}$$

This estimation can be used to maximize the profit. Attributes such as fee can be varied to find the optimal values:

8.15 $$\max[E[\text{Profit}]] = \max[P_o(win) * (F_e - C_e)]$$

8.4.2 Negotiations

Most negotiations are centered on contract details when the fee proposal is included in the proposal stage. However, if the fee is further negotiated, Value-Bidding provides a tool for quantifying the market worth of the services offered. Equations and methods presented in earlier chapters assist the design firm in determining the value of their services in terms of dollars. For instance, recall the equation for the likelihood of purchase:

8.16 $$P(U_\varphi) = \frac{e^{U_\varphi}}{\sum_{\varphi=1}^{\Phi} e^{U_\varphi}}$$

This analysis presents the relative acceptance of fee ranges, given the attributes of the design firm.

The goal to maximize profit is important to maintain throughout the negotiation phase. The Value-Bidding Model supplies the negotiators with the knowledge of what the owner values, which gives them a stronger negotiating position.

References

Friedman. L., (1956) "A Competitive Bidding Strategy" Operations Research. Vol. 4. 1956, pg. 104-112.

Griffis. F.H. (Bud), and John V. Farr, (2000) Construction Planning for Engineers, McGraw Hill, New York, 2000.

Paranka, Stephen, (1971) "Competitive Bidding Strategy, A Procedure for Pre-Bid Analysis," Business Horizons, Vol. 14, June 1971, pg. 39-43.

Phipps. Alan R.. (2000) "Box Girder Balancing Act" Civil Engineering, ASCE, March 2000. pg. 33-39.

Stasiowski, Frank A. (1993), Value Pricing for the Design Firm, John Wiley & Sons, Inc., New York, 1993.

Chapter 9

Case Study – Columbia University Projects

"The ultimate test when applying any bidding strategy is that the answer must appeal to your sense of reason."

-Marvin Gates, President, Construction Estimating, Inc., 1967

9.1 Introduction

This chapter presents a case study conducted at Columbia University in New York City. The procurement process for architectural design services was studied. The author interviewed and conducted a small conjoint study with a project management group, an office of O'Brien-Kreitzberg (a subsidiary of URS Construction Services), OKB in charge of project oversight for all construction projects at the university. OKB also provided competitor and fee data pertaining to three projects. The data collected was modified to maintain confidentiality. The three projects will be referred to as project 39, project 82 and project 40. The author would like to express her gratitude to the Columbia University URS office for their support and participation in this study.

The Columbia University OKB office was chosen for this case study because of the numerous project managers together in one office who make decisions regarding the procurement of designers. Furthermore, they represent a single multi-job client, the university. This is a self-contained sample set for the conjoint model and OKB provided the author access to a group of similar projects, which could be studied.

9.2 Preliminary Study – Attribute Development and Preliminary Survey

The author conducted a preliminary survey to identify the factors that influence the owners' or owner representatives' selection of architectural and engineering design services. The respondents were asked to name attributes of the design service, which influenced their selection, and to rank these attributes in order of importance. From this preliminary study, the attributes for the case study were selected. The following is a list of influential attributes of design services and the corresponding ratings:

Attribute of Design Service	1st	2nd	3rd	4^{th}	5th
Team expertise	20%	40%	20%		
Price	40%		20%	40%	
Owner's Personal knowledge of firm	20%	10%	10%	40%	
Owner's Personal knowledge of team		30%	10%		
Firm's past projects	20%	20%	20%		
Schedule, shortest schedule with credibility			20%		
Reputation				10%	
Location (familiar with local codes)				10%	20%
Accessibility of design firm and proximity to job site					20%
Work load of project team					20%
None					40%

Table 9.1 Attributes of Design Services, Ranking Frequencies

The results show ambiguous agreement regarding the order of importance for these attributes. The top five important factors are clear: The Personnel's Technical Expertise, the Price, the Owner's Personal Experience with Both the Firm and the Team Members, and the Firm's Past Projects. The fourth and fifth ranked factors are more diverse and varied. These attributes included: reputation, location (familiar with local codes), accessibility of design firm, proximity to job site, and current workload of design team. These attributes were not included in the study.

Note that in this case it is difficult to capture a clear sense of ranking, i.e., most influential attributes. In fact, one respondent was asked at two different times (first during a preliminary interview, and second in the preliminary survey) to name and rank the attributes that influence the choice of a design firm. This respondent named similar attributes in each set, but put them in almost a reverse order in the survey from the first list given in the interview. One can conclude that the most influential attributes may be the similar, but the order of importance may vary for different projects, or that there is not strong sense of one attribute being far more important than the others, and that it is the best overall package that counts. Therefore, it is important to compare the design firms as profiles of attributes and not study the attributes independently (i.e., self-explication analysis of choice attributes).

To keep the number of possible profiles within a workable number, 3 attributes were chosen for this case study. These attributes were modeled so as to incorporate several of the most important factors listed above:

1. Owner's previous experience with design firm
2. Experience of firm and key personnel
3. Price (% of total Project Cost)

For the conjoint analysis, once the attributes are chosen, the next step is to develop levels (See Diagram 5.1). The most difficult and controversial attribute to model was the price. Price can be referred to in a variety of ways. For instance, the design fee can be expressed as the percentage of construction costs, a percentage of total installed or total project costs, or levels might be designated as lowest, low, average, high, highest. The difficulty lies in the necessity to make the levels generic, whereas the fee values and percentages vary from job to job. Though the percentage of project or construction costs is a generic representation of the proposal fee levels, the reasonable percentage levels often vary based on the size and type of the job in question. During the preliminary study, one respondent commented:

"With respect to gauging the prices, there are industry guidelines and norms that are used to validate and confirm numbers, and these can be extensive. However a fundamental one is engineering cost as a percentage of total installed cost. In the process world, for instance, for a new facility this will be in the 10% to 15%. A modification to existing facility will be higher and in the range of 15% to 25%. In the power industry, this percentage is much lower due to the major cost of the turbine and generator. Engineering usually is in the 5% to 7% range. Fees or profit vary a large amount. Today is a very competitive market, and 5% profit or less is not unusual."

Therefore, the author concludes that when the fee is included in the conjoint study, the fee levels should be developed for each industry segment and each segment should be analyzed independently from the others. The assumption behind these attributes and levels is that the project managers in this case study hire designers for similar projects. Projects range from single room renovations to new building construction.

1) **Price (% of Total Project Cost)**
levels:
a) *1-3* % of total job cost
b) *4-6* % of total job cost
c) *7-9* % of total job cost
d) *10-12*% of total job cost
e) *13-15*% of total job cost

This attribute is the price of the engineering service in percent of total installed cost. For example, if the total estimated project cost were 1 million dollars, the design fee would be $10,000 - $30,000 for level a, $40,000 - $60,000, for level b, etc.

The other two attributes were developed as follows:

2) Previous work with design firm

levels:

a) ***several*** jobs, ***positive*** experience
b) ***one*** job, ***positive*** experience
c) ***no*** previous jobs
d) ***one*** job, ***negative*** experience
e) ***several*** jobs, ***negative*** experience

This attribute describes the number of jobs this design firm has done with the owners or owner representatives, and whether that experience was mostly positive or negative.

3) Experience of firm and of key personnel

levels:

a) Firm experience : ***no*** similar jobs
   Key Personnel experience : ***no*** similar jobs
b) Firm experience : ***one*** similar job
   Key personnel experience : ***no*** similar jobs
c) Firm experience : ***many*** similar jobs
   Key Personnel: ***no*** similar jobs
d) Firm experience : ***no*** similar jobs
   Key Personnel: ***many*** similar jobs
e) Firm experience : ***one*** similar job
   Key Personnel: ***many*** similar jobs
f) Firm experience : ***many*** similar jobs
   Key Personnel: ***many*** similar jobs

Firms include corporate resumes as well as individual resumes for key personnel assigned to the project. This attribute describes the type of jobs presented in these resumes. This attribute refers to the job TYPE, not overall engineering expertise. This attribute describes the job experience of both the firm and the key personnel. "No Similar Jobs" refers to the fact that there are no similar jobs in corporate or personal history, "One Similar Job" conveys the fact that there is one job in the corporate history, and "Many Similar Jobs" conveys the fact that the firm or personnel have a lot of experience in the type of job they are proposing for.

For example, a firm might have worked on many hospital jobs in the past, but they have not worked for a university before. They would have no similar jobs in corporate experience for university construction, but they are still very qualified engineers, technically speaking). With the attributes and levels defined, a conjoint study was then developed. The next section describes the conjoint study and the results.

9.3 Conjoint Study, Project Managers

9.3.1 The Conjoint Survey

A choice-based conjoint survey was developed with the above attributes and levels. There were three profiles per choice question, and a total of ten choice questions per survey. Out of the ten choice questions, eight were random and two were fixed. Random questions differ for each version of the survey, whereas the fixed questions compared the same three profiles in every survey version. Sawtooth Software's CBC version 2.6 (Choice-Based Conjoint) was used for questionnaire development and respondent analysis. For random choice questions, CBC 2.6 selects a level at random for each attribute and generates choice questions that conform to the following principles (Orme, 1999):

1. Minimal Overlap. The software attempts to show an attribute level only once per question.
2. Level Balance. Throughout the questionnaire, CBC attempts to show each level an equal number of times.
3. Orthogonality. Attribute levels are independent of other attribute levels. This is to ensure that the level's effects (utilities) can be independently measured.

Out of the ten choice questions asked per survey, number 5 and 8 were fixed. In other words, questions 5 and 8 were the same for every respondent. Figure 9.1 shows an example question from the choice-based conjoint study. A complete survey is shown in Appendix C.

Question 5

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A
(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost

CHECK BOX ☐

FIRM B
(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost

CHECK BOX ☐

FIRM C
(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost

CHECK BOX ☐

Figure 9.1 Example Question Page From Survey

Although the surveys could be conducted via a computer program, the author chose to do a paper and pencil survey. Paper surveys gave the respondents more leeway to add comments during the follow-up questions, see Appendix C, and these comments provided valuable feedback as to the attributes and levels presented. The surveys were distributed to the group of project managers who manage Columbia University's capital improvement projects and were collected at the end of a month's time. There was a 26% completion rate.

9.3.2 Attribute Utility Values

The responses were accumulated and then analyzed with CBC version 2.6. This conjoint case study generated the following utility values:

	Utility	Attribute Level
1	3.4	Several previous jobs, Positive experience
2	1.3	One previous job, Positive experience
3	0.0	No previous jobs
4	-1.5	One previous job, Negative experience
5	-3.3	Several previous jobs, Negative experience
1	-2.7	firm: 0 similar jobs & key personnel: 0 similar jobs
2	-2.4	firm: 1 similar job & key personnel: 0 similar jobs
3	0.2	firm experience: MANY & key personnel: 0
4	0.9	firm experience: 0 & key personnel: MANY
5	3.2	firm experience: 1 & key personnel: MANY
6	0.9	firm experience: MANY & key personnel: MANY
1	1.6	fee = 1-3 % job cost
2	0.5	fee = 4-6 % job cost
3	0.2	fee = 7-9 % job cost
4	-0.6	fee = 10-12 % job cost
5	-1.7	fee = 13-15% job cost

Table 9.2 Utilities for Case Study Conjoint Analysis with OKB

These values are as anticipated, except for the second attribute in the list: Firm and Personnel Experience. For this attribute's last three levels, the case study conjoint analysis produces an unanticipated series of utilities; level 5 is weighed much higher than level 4 and 6. Intuitively, one might assume that as the experience increases, so would the utility. The error introduced may be caused by the small case study sample, which may have contributed to the difficulty of capturing the true effects of this attribute. There is no perceivable reason that the project managers would prefer level 5, (Firm Experience: one, personnel experience: many), with a utility of 3.2, to level 6, (both Firm and Personnel Experience: many) with a utility of .9. To correct for this error, the author assumes a more symmetrical utility value structure for this attribute, which is evident in the other two attributes. In other words, the author assumes that the project managers might have a positive utility for more experience that mirrors their negative utility for little or no experience. Post survey interviews confirm this assumption. Therefore, the adjusted utilities are presented here for attribute 2, firm and personnel experience. There was an attempt made to maintain the original range of 5.9 while honoring the symmetry of the attribute utility levels:

1	-2.5	firm: 0 similar jobs & key personnel: 0 similar jobs
2	-2.2	firm: 1 similar job & key personnel: 0 similar jobs
3	0.3	firm experience: MANY & key personnel: 0
4	1	firm experience: 0 & key personnel: MANY
5	3.4	firm experience: greater than 1 & key personnel: MANY

Table 9.3 Adjusted Utilities for Attribute 2, Firm and Personnel Experience

9.3.3 Utility Ranges

The relative importance of each attribute can often be determined from the utility ranges. The attribute utility ranges for this case study are:

Range	Attribute
6.7	Previous work with design firm
5.9	Experience of firm and of key personnel
3.3	Price (% of Total Project Cost)

Table 9.4 Utility Ranges for Case Study, OKB

The previous work with design firm rates much higher than the price, which reflects the priorities of the respondents. The URS O'Brien Kreitzberg project managers are owner representatives. While they are careful to manage the owner's budget, the money they are spending is not their own. Therefore, they would be more interested in making their management job easier, and arguably improving the quality of the job, by working with designers whom they have worked with in the past and who they know will be productive, efficient and responsive. It follows then, that they place more value on the relationship with the designer than the proposal price.

Another possible influence on these attribute ratings is that the respondents might feel that a lower fee does not necessarily result in lower overall cost of the project. The designer with a low fee can increase construction costs by delaying design decisions, shop drawing approvals and so forth. Therefore, the respondents may place more weight on a reliable designer because they believe reliability improves quality.

9.3.4 Holdout Test

One can verify the reliability of these attribute level utilities by measuring their ability to predict choice using the hold out or fixed choice questions. The utilities were calculated using only the random choice answers. Therefore, the author uses the two fixed questions, question 5 and 8, to analyze the predictability of this conjoint model. Recall the probability of winning can be written as:

9.1 $$P_o(win) = \frac{e^{V_o}}{\sum_{i=1}^{n} e^{V_i}}$$

Using this equation, the conjoint model predicts the probability of winning, presented in the first column of the table below. In comparison, the respondent rates are listed in the second column, and column three compares these two columns:

Question 5			
	Prediction	Respondents	error
P(Awin)	30%	40%	10%
P(Bwin)	42%	40%	2%
P(Cwin)	27%	20%	7%
Question 8			
	Prediction	Respondents	error
P(Awin)	86%	80%	6%
P(Bwin)	7%	0%	7%
P(Cwin)	8%	20%	12%
		Average error	7%

Table 9.5 Predictability Test for the Model Calibration

For these two fixed holdout questions, the conjoint model performs well.

9.4 Competitor Profile Development

OKB gave the author a list of architects and subconsultants who submitted proposals for three jobs, and the fee proposals for each. No information was given as to previous work with each architect or proposed subcontractors, and the author did not inspect the proposals themselves. Consequently, the competitor analysis was conducted with uncertainty that parallels a designer's knowledge regarding the marketplace and competition. Realistically, it is difficult to ascertain an owner's perception of a design firm and it's competitors, but public information, industry contacts, personal experience and intuition provide clues. One can then formulate probabilities of competitor profile existence based on accumulated knowledge.

To preserve the confidentiality of the participants, the data has been modified, but the values are proportional to reality. Three projects were studied. Each project had a different set of competitors.

9.4.1 Project 39

For each competitor, there is a need to determine the applicable attributes levels. Due to uncertainty regarding one's knowledge of the competitors, one might need to develop a probability of existence distribution across several conjoint attribute levels. For example, the following is a possible distribution for hypothetical Firm G.

Attribute	Level	Firm G
Previous work with design firm		
1	Several jobs, positive experience	10%
2	One job, positive experience	15%
3	No previous jobs	60%
4	One job, negative experience	10%
5	Several jobs, negative experience	5%
	Check sum	100%
Experience of firm and key personnel		
A	Firm: None, Personnel: None	16.6%
B	Firm: One, Personnel: None	16.6%
C	Firm: Many, Personnel: None	16.6%
D	Firm: None, Personnel: Many	16.6%
E	Firm: One, Personnel: Many	16.6%
F	Firm: Many, Personnel: Many	16.6%
	Check sum	100%
Price (% of total Project Cost)		
	1-3%	
	4-6%	25%
	7-9%	50%
	10-12%	25%
	13-15%	
	Check sum	100%

Table 9.6 Example Probability of Existence Distribution for Hypothetical Firm G

To develop the probability distributions for this case study, past project data was gathered from public information sources. Appendix B lists possible sources of information regarding competitor experience and expertise. A thorough search was conducted via the Internet regarding the architects' past and current projects. Given this information, the author was able to estimate the probable levels for attributes one and two, Previous Work with Design Firm, and Past Experience of Firm and Personnel.

For example, Architect C is an AIA member. Their address, phone and fax number, web page and e-mail are listed on the AIA website. Firm C lists higher education under their client groups, and engineering schools under building types. The firm definitely has experience in this type of project, and if they want to win the job, they will likely put experienced personnel on the job as well. However, there is a chance that they will not or cannot put experienced personnel on the job. Furthermore, there is a chance that the selection group for project 39, is not familiar with the work Firm C did on the Columbia Law building. Therefore, there is a chance that they do not have experience with them, but past experience at Columbia would be somewhat valuable, even if they have not worked directly with the current selection committee. We also observe that they have a regional office in close proximity to the job. However, Columbia University is not listed under past projects on Firm C's website. The investigation should continue.

From a telecommunications supplier's web site, the author found that Architect C was involved in a project at the university's law school, which was completed in 1999. Therefore, one can conclude that Architect C conducted at least one job at the university and with OKB, since OKB has been working with the university projects since 1996.

Further search resulted in no other references to other projects by Firm C at the University. Therefore, we may assume that the likelihood of their having multiple projects with OKB is fairly low. The probabilities therefore, might be represented as in the following table. This investigative and deductive process is repeated for each potential competitor. The following table presents the resulting probability distributions:

Attribute Level	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
Previous work with design firm						
Several jobs, positive experience	.10	.06	.10	.05	.10	.03
One job, positive experience	.15	.60	.40	.15	.50	.15
No previous jobs	.60	.04	.15	.75		.65
One job, negative experience	.10	.26	.25	.05	.30	.15
Several jobs, negative experience	.05	.04	.10		.10	.03
Experience of firm and key personnel						
Firm: None, Personnel: None	.13					.18
Firm: One, Personnel: None	.25	.10	.05		.05	.18
Firm: Many, Personnel: None	.20	.15	.10	.05	.10	.12
Firm: None, Personnel: Many	.13					.12
Firm: Many, Personnel: Many	.30	.75	.85	.95	.85	.40
Price (% of total Project Cost)						
1-3%						
4-6%		1.00				
7-9%	1.00		1.00	1.00		
10-12%					1.00	1.00
13-15%						

Table 9.7 Probability Distributions for Project 39

For this case study, the author obtained the proposal fees presented by each firm. To simplify the analysis, these exact fees were used with a hundred percent predictability. Since the proposal fees were provided, some of the analysis was conducted with 100% confidence of the competitor's proposals. However, this information would not generally be readily available to a designer who would be using the Value-Bidding Model to develop a proposal.

9.4.2 Project 83

Similar analysis was conducted for the competitors in Project 83. One of the competitors was heavily favored on this particular project, because they worked on a previous project in the same building for the same project manager. However, the job was publicly advertised, and architects were invited to submit proposals. This is a common strategy by an owner to procure a competitive price from the architect. If their fee is reasonable, the favored designer will be awarded the job. With this knowledge, and public information accumulated from the Internet, the following probabilities of existence were estimated:

Attribute	Level	Firm A	Firm B	Firm C	Firm D	Firm E
Previous work with design firm						
	Several jobs, positive experience	.78				.65
	One job, positive experience	.15	.05	.10	.10	.20
	No previous jobs		.90	.85	.85	
	One job, negative experience	.05	.05	.05	.05	.10
	Several jobs, negative experience	.02				.05
Experience of firm and key personnel						
	Firm: None, Personnel: None					
	Firm: One, Personnel: None					
	Firm: Many, Personnel: None	.10	.60	.50	.50	.35
	Firm: None, Personnel: Many					
	Firm: One, Personnel: Many	.90	.40	.50	.50	.60
Price (% of total Project Cost)						
	1-3%					
	4-6%	1.00			1.00	
	7-9%		1.00			
	10-12%			1.00		1.00
	13-15%					

Table 9.8 Probability Distributions for Competitors in Project 82

9.4.3 Project 40

Project 40 is another project built on the Columbia University campus. The market research justified these probabilities of existence:

Attribute	Level	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
Previous work with design firm							
	Several jobs, positive experience	.10				.05	.10
	One job, positive experience	.35	.10	.40	.03	.10	.55
	No previous jobs	.10	.85	.55	.95	.70	
	One job, negative experience	.35	.05	.05	.03	.10	.25
	Several jobs, negative experience	.10				.05	.10
Experience of firm and key personnel							
	Firm: None, Personnel: None				.35	.22	
	Firm: One, Personnel: None				.25	.18	.15
	Firm: Many, Personnel: None	.50	.50	.35	.10	.12	.25
	Firm: None, Personnel: Many				.10	.18	
	Firm: One, Personnel: Many	.50	.50	.65	.20	.30	.60
Price (% of total Project Cost)							
	1-3%						
	4-6%		1.00				1.00
	7-9%	1.00		1.00	1.00		
	10-12%					1.00	
	13-15%						

Table 9.9 Probability Distributions for the Probability of Existence for Competitors in Project 40

These probabilities will be incorporated into the probability of winning in the Value-Bidding Model. The determination of competitor's attributes and the probability distributions of those attributes influence the probability of winning. It is important that these probabilities are modeled as accurately and consistently as possible. Chapter 6 discusses these issues at length. When developing probability distributions from subjective data, consistency is imperative.

9.4.4 Average Competitor

The probabilities were combined to create an average competitor distribution. It was assumed that all of the competitors fall into the average competitor category.

Realistically, firms may compete against known competitors who do not represent the typical type of competitor, and including this unique competitor in the profile average may skew the resulting average competitor profile. Some consideration should be given to the type of firms who make up the average competitor distribution. The average competitor distribution for this case study is as follows:

Attribute	Level	Average Competitor
Previous work with design firm		
	Several jobs, positive experience	.117
	One job, positive experience	.234
	No previous jobs	.485
	One job, negative experience	.129
	Several jobs, negative experience	.036
Experience of firm and key personnel		
	Firm: None, Personnel: None	.05
	Firm: One, Personnel: None	.08
	Firm: Many, Personnel: None	.26
	Firm: None, Personnel: Many	.05
	Firm: One, Personnel: Many	.56
Price (% of total Project Cost)		
	1-3%	0
	4-6%	.29
	7-9%	.41
	10-12%	.29
	13-15%	0

Table 9.10 Probability Distributions for the Case Study Average Competitor

As discussed in Chapter 6, one can use the average competitor to model unknown competitors. The full distribution of the average competitor represents the probability of existence of a truly unknown competitor, where as an average competitor might be simplified to reflect industry specific or personal knowledge.

9.5 Value-Bidding Analysis

Analysis was conducted on all three projects to illustrate the Value-Bidding methodology and demonstrate the potential viability of the Value-Bidding Model. As discussed in Chapters 5, 7 and 8, there are many questions that can be addressed using Value-Bidding. For example, a firm could use Value-Bidding to determine when it is in their best interest to submit or to forgo a proposal. Value-Bidding is also useful when they want to maximize the probability of winning, or a firm may want to maximize profits.

9.5.1 Determining the Probability of Winning

For this case study, the author developed analytical computer programs using MatLab Version 5. The details of these programs are discussed in Appendix D. These programs are generalized and can be used for a range of 2 to 6 competitors. Furthermore, the programs can be easily modified to accommodate more competitors.

<u>Projects 39 & 82</u>

Given the input data presented in the preceding section, the results, (presented here for all firms) are an estimation of the probability of winning over the competitors:

Project 39	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
P (win)	.09	.29	.28	.19	.13	.03

Table 9.11 Probability of Winning Data for Case Study Project 39

OKB actually chose Firm D for Project 39, though it was not the favorite in this analysis. It should be noted that Firm D does have a greater than average chance of winning this particular job. Furthermore, there are many factors not taken into account in the model. Each firm did an oral presentation as part of the proposal process. Post survey interviews revealed that the selection committee relied on the presentations as a gauge as to how much the firm wanted the job, how well the team was put together, and how the personalities would work with the OKB project managers. The selection panel looks for a firm they feel good about. The Value-Bidding methodology attempts to capture and model these feelings. Factors such as a firm's desire to win, were not modeled in this case study Value-Bidding analysis. Further research is warranted to determine useful and efficient attributes that best model the selection of engineering and architectural design services.

The Value-Bidding Model provides insight in this case study, and gives the engineer valuable information about both the owner's priorities and the competition. First, if all of the competitors are equal, there is a 1/6 or 17% chance of winning. With a 19% probability of winning, Firm D has a greater than average chance of winning the proposal. These odds of winning may justify the cost of preparing a proposal.

Second, from the conjoint analysis data, Firm D realizes that repeat work is the most valuable attribute to OKB. If they win one proposal, and the OKB team is happy with their performance, the next proposal is weighted more heavily in their favor. As discussed in Chapter 7, this is a strategy that maximizes the probability of winning for this and future projects. Recall, to maximize the probability of winning, the engineering firm must maximize each attribute in turn.

- Attribute one: Previous Work with Owner. If Firm D has not worked previously with the owner, it is difficult to move up in this attribute for the initial project. However, they might take steps to capitalize on their strengths, and highlight other similar projects and owners who were satisfied with their work. After one successful project, Firm D has most likely improved their utility in attribute 1.

- Attribute two: Previous Experience of Firm and Key Personnel. Firm D can capitalize on the firm's experience, and can maximize this attribute by putting experienced key personnel in this proposal. Once a design team has worked with an owner, and the owner or owner representatives get to know the team and feel comfortable and confident with them, a second job may be easier to win.

This is exactly what happened. Project 82 is a follow up project for Project 39. Firm D submits a proposal for this new job, and the resulting probabilities of winning are:

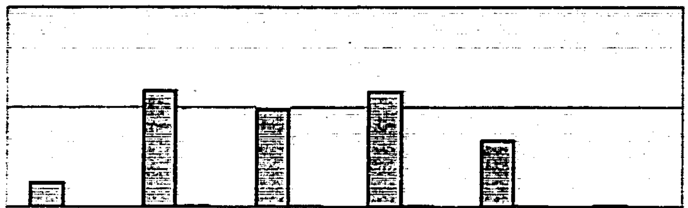
Project 82	Firm A	Firm B	Firm C	Firm D	Firm E
P (win)	.025	.026	.050	.702	.223

Table 9.12 Probability of Winning Data for Case Study Project 82

Firm D has an obvious advantage in this proposal.

Since the fee is an attribute in this case study, the Quality-based Selection presented in Chapter 7 is relevant. Recall, the goal is to maximize the utility to fee ratio to achieve the highest value in relation to the fee.

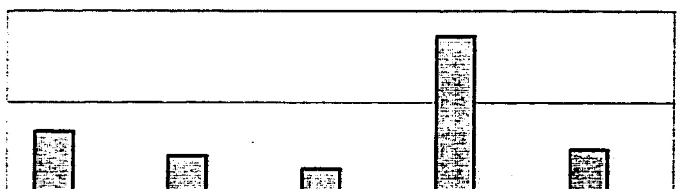
Project 39 - Quality-Based Selection Analysis



	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
Ratio	12.0	57.9	48.6	57.5	33.1	0.6
Percent of total	6%	28%	23%	27%	16%	0%

Figure 9.2 Project 39, Quality-Based Selection Analysis

Project 82 - Quality-Based Selection Analysis



	Firm A	Firm B	Firm C	Firm D	Firm E
Ratio	33.9	20.4	13.4	85.9	24.0
Percent of Total	19%	12%	8%	48%	14%

Figure 9.3 Project 82, Quality Based Selection Analysis

This analysis is a better prediction of the final result, the selection of Firm D in both cases. For project 39, it was a toss up between Firm B and Firm D, with Firm C also in strong competition. It is also clear that there is no room to increase the fee.

For Project 82, Firm D is the clear winner. Furthermore, there is likely room to increase the fee. If the fee is increased 20%. Firm D still has a 20% higher utility to fee ratio and is the likely winner. To improve profitability, Firm D could recognize this advantage and might propose a higher fee in this case.

Project 40

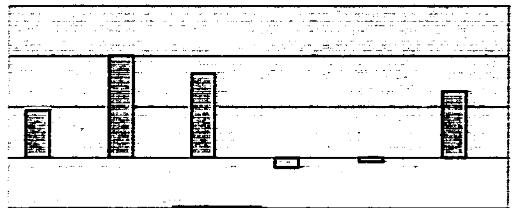
Project 40 is a separate project from the previous two projects. There is a different OKB project manager heading up this project, but the general conjoint utilities are used. The probabilities of winning are as follows:

Project 40	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
P(win)	.16	.21	.30	.06	.06	.21

Table 9.13 Probability of Winning Data for Case Study Project 40

And the Quality-Based Selection analysis results:

Project 40 - Quality-Based Selection Analysis



	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F
Ratio	45.5	100.1	83.4	-9.4	-3.5	65.4
Percentage of Total	15%	33%	27%	3%	1%	21%

Figure 9.4 Project 40, Quality-Based Selection Analysis

This project is not as clear-cut as the previous two. In the probability of winning analysis. Firm F appears to be the strongest and most likely candidate; whereas in the Quality-Based selection analysis, Firm F lags behind Firm B and C. Firm C eventually won this project.

9.5.2 Maximize Profit

A firm may only wish to win a job if it is profitable, and their main business goal might be to maximize profit. This methodology was discussed in detail in Chapter 8. Recall, the profit is equal to the probability of winning times the fee minus the cost.

9.2 $$E[\Pr ofit] = P(win) * (F_e - C_e)$$

where F_e is the estimated fee, C_e s the estimated project cost, and P(win) is the probability of winning given the fee. For this analysis, Firm D in project 39 was used and the probability of winning was calculated, while varying the fee from the range 1-3% to 13-15%:

Project 39	1-3%	4-6%	7-9%	10-12%	13-15%
P(win) for Firm D	.48	.23	.19	.09	.03

Table 9.14 Project 39, the Probabilities of Winning for Firm D Given a Variable Fee Value

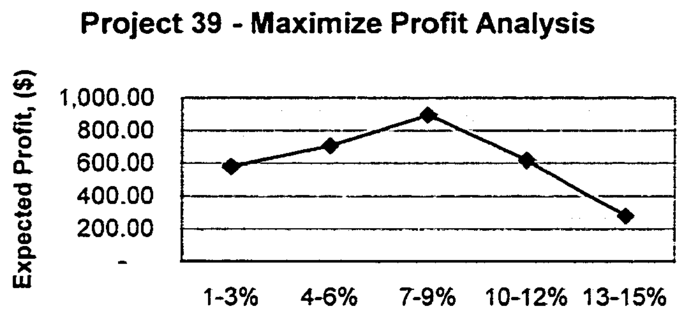


Figure 9.5 Project 39, Profit Maximization Analysis

Firm D for project 39 submitted a proposal fee of 7.6%. They were in the most profitable range.

In the post survey interviews, several of the respondents observed that the fee ranges were unrealistic and that in reality the fees are closer together. Project fees may differ by less then one percent of project costs. This is an issue for the profit maximization analysis as well. For example, a range of 7-9% in the above example is fairly broad. The base profit ($F_e - C_e$) for a 7% fee is much lower than a 9% fee. However, in the ranges used for the case study, all fees ranging from 7 to 9 % are included in one category. The profit model would be more useful if the fee was indicated with greater specificity. Though fees vary across industries and geographical areas, researchers using the Value-Bidding methodology should pay particular attention to the definition of the attribute levels for the fee. For instance, in subsequent analysis, the fees in the OKB case study, the fees ranged from 4.5% to 13.5%, but most fees were in the range of 6 to 8%. In this case, outliers, (fees greater than 13 and less then 4) could be managed with a greater than or less than statement, while the more common percentages are specified:

Level 1 – less than 5%
Level 2 – 5%-5.9%
Level 3 – 6-6.9%
Level 4 – 7-7.9%
Level 5 – 8-8.9%
Level 6 – greater than 9 %

Table 9.15 Example Potential Attribute Level Structure for the Design Fee Attribute

9.6 Comments and Conclusions

This case study illustrates Value-Bidding's potential as an indicator of the competitive environment as it is influenced by the owner's preferences. The model can be used to strengthen a proposal by drawing attention to the attributes of the engineering service that the owner deems valuable. Value-Bidding should be used to support the proposal preparation and presentation process, but it cannot guarantee the outcome. Value-Bidding results should be considered in conjunction with other factors and issues that reflect the specifics of the proposal and presentation.

The case study presented in this chapter is not presented as empirical proof of Value-Bidding's applicability to all sectors of engineering services, or to a greater market audience. It is just one case and is used as an example to illustrate the Value-Bidding method put into practice, and to demonstrate the predictive potential of this methodology.

Value-Bidding is a new method of modeling the complexities of selling engineering design services. As does any new methodology, Value-Bidding needs to be analyzed, compared and refined. Further research could be conducted to refine the methods of competitor data collection and probability of profile existence development. Emperical research could be performed to determine limits, industries or areas of validity, applicability, and sensitivity to uncertainty.

References

Hanselman, Duane, and Bruce Littlefield, The Student Edition of MATLAB, Version 5, User's Guide, The Math Works Inc., Prentice Hall, Upper Saddle River, NJ, 1997.

Orme, Bryan, Editor, (1999) CBC User Manual, Version 2.0, Sawtooth Software, Inc., Sequim, WA. http://www.sawtoothsoftware.com

Chapter 10
Conclusion

"Never fear the want of business. A man who qualifies himself well for his calling, never fails of employment."

Thomas Jefferson (1743 - 1826)

10.1 Summary

10.1.1 Introduction

The motivation behind the theoretical development described in this dissertation can be summarized as follows: Information technology is revolutionizing the engineering industry. Design fees based on labor hours often no longer reflect the value of the services rendered, and profitability has drastically declined in the industry as a whole. In order to stay profitable, engineers must determine the fair market value of their services in light of new technology and marketplace.

In pursuit of an analytical method to address these issues, the author has incorporated and developed very flexible methodologies, namely Value-Bidding competitive analysis, whereby engineers can determine the valuable attributes of their services in the eyes of their clients. Value-Bidding enables engineers to analyze market conditions, evaluate owner's priorities, systematically track competitors, and optimize job proposals, while maximizing the probability of winning, maximizing profit and optimizing bid prices.

Although the civil engineering industry is addressed specifically, the Value-Bidding model is applicable to any procurement process where an individual or a firm submits proposals in competition with other firms to supply products or services and where the selection criteria is based on multiple factors, including quality, location, availability, firm reputation, and possibly but not necessarily price.

10.1.2 The Value-Bidding Model

This dissertation is a unique treatment of competitive bidding theory. Many traditional probability-based competitive bidding models analyze a single factor, the bid. The methodology presented here utilizes an established marketing research tool, conjoint analysis, to predict a value-based probability of winning. Consequently, Value-Bidding refocuses the competitive bidding models from a fee-based to a value-based selection criterion.

As presented in Chapters 5 and 6, the steps of the Value-Bidding methodology can be summarized as follows:

1) Conjoint analysis
    a. Market sector definition
    b. Product or service definition
    c. Product or service attribute definition
    d. Model Calibration
        i. Survey clients as to what profiles they prefer
        ii. Analysis Survey data and determine part-worths or utility weights
2) Competitor profile definition
    a. Market research
        i. Industry data collection
        ii. Database formation
    b. Competitor profiles definition in relation to owner or market section
    c. Average and unknown competitor profile calculation
3) Probability of winning estimation
    a. Competitor sets determination
    b. The probability of winning evaluation
    c. The combination of the probabilities of winning with the probabilities of existence of the competitor sets (two method presented in Chapter 5)
    d. The overall probability of winning determination
4) Uses for the data and metrics
    a. Proposal submission decision (submit or do not submit)
    b. Proposal optimization.
        i. Evaluation of the probability of winning against competition
        ii. The probability of winning maximization
        iii. Profit maximization
        iv. Designation of areas to improve and business strategy development to achieve these improvements
        v. Price optimization
        vi. Evaluation of alternatives and services (i.e., new technology)

One of the key contributions of this dissertation is the value-based probability of winning. There are two inputs streams that create the Value-Bidding probability of winning. One source is a conjoint study of owners. The second is a marketing study of competitors, which results in the development of probabilities of competitor profile existence. Figure 5.4 shows a diagram of the development of the Value-Bidding probability of winning.

Detailed discussions of the Value-Bidding Model and potential uses were discussed in chapters 4 through 9. Chapter 4 introduced conjoint analysis and discusses the state-of-the-art for choice-based conjoint. Chapter 5 gave a detailed description of the Value-Bidding equations as well as a development from fundamental principles. Chapter 6 described the development of the probabilities of profile existence, and discusses known, average and unknown bidders as well as data collection issues.

10.2 Potential Applications of this Research

10.2.1 Inside the Scope of this Dissertation

Value-Bidding was developed to support the pricing of engineering design services. Engineers optimize prices based on diverse business goals, e.g., maximize profit, expand into new territory or maximize work volume. The methodology presented in Chapters 7 and 8 addresses the pricing and profitability of engineering services within the context of the competitive proposal environment. The procurement process for engineering services can be generalized as follows:

Owner	Designer
1. Request for Proposals	
2. Submit or not submit a proposal?	
	3. Business goals ▫ Win the job ▫ Maximize profit4. Select short list
(Quality based selection)	
	5. Oral Presentation
6. Negotiations and contract	

Table 10.1 Procurement Process for Engineering Design Services

Value-Bidding analysis supports the designer's decisions and actions in this process. Preliminary analysis can support the decision whether to submit a proposal or not be indicating whether there is a fair chance of winning. More detailed analysis can be conducted to develop written proposals and proposal prices. For instance, if the goal is to maximize the profit, an engineer could use the following analysis to indicate an optimal proposal price:

$$\text{(10.1)} \qquad \text{Max}\,[\text{E}[\text{Profit}]] = \max[P(win(\phi)) * (F_e(\phi) - C_e)]$$

The expected value of the potential profit can be estimated as the proposal price, F_e, minus the cost, C_e, times the probability of winning the job, $P(win(\phi))$. In this case the proposal price, F_e and the probability of winning are functions of the conjoint attribute, ϕ, which represents the generalized proposal price attribute. In order to maximize profit, classical bidding theory suggests that the expected profit be maximized. Though the resulting proposal price maybe too high to win a specific job, theoretically, the aggregate of all proposals will result in the highest possible profit.

Other analysis can be conducted to maximize the likelihood of winning. The pursuit of a job may have precedence over profit. For instance, if the firm would like to expand into a new technological arena, they need to acquire jobs in this field to build a completive corporate resume. This and other potential applications of Value-Bidding analysis were discussed in detail in Chapters 7 and 8, and the application of these analyses was presented in the case study, Chapter 9.

10.2.2 Outside the Scope of this Dissertation

First, the author believes that the Value-Bidding methodology has a broad application potential, both inside and outside of the engineering industry. The Value-Bidding model could be potentially useful in any industry when there are multiple factors in the selection criteria. For example, in the manufacturing industry, a parts supplier is often judged on quality, past performance, location, flexibility, available resources, as well as price. Value-Bidding allows the parts manufacturer to evaluate the owner's priorities, the competitor's ability to meet the owner's requirements, as well as establish a model of their own competitive advantage in certain markets and for certain owners.

Second, Value-Bidding could be used to analysis new technological developments, such as three-dimensional computer models and associated databases. The effects of new technology on a firm's competitive advantage could be evaluated. Using Value-Bidding, engineers can investigate the owner's perceived added-value of this technology, and compare their technological as well as professional profile with their competitors. This analysis may support information technology investment decisions. For example, owners in the process industry are beginning to value three-dimensional computer models and integrated databases (Phair and Powers, 1998) Engineers pursuing work in this industry could use Value-Bidding to evaluate new integration technologies. If the owners do not value a certain technological improvement, the expense of implementing this new technology may not be justified.

This type of evaluation is not limited to new technologies. As discussed in Chapter 2, the market is changing, and with this change the relationship between owner and design consultant is shifting, particularly with regards to fee and price expectations. Today the market is very competitive and owners are more price sensitive. Research is ongoing to develop ways of differentiating one's firm from competitors and increasing the perceived value of the engineering design services (CII, 2000). For example, possible areas of differentiation might include:

1. Project ingenuity with regard to: environmental, social, political, technical and financial constraints.
2. Construction savings – value engineering, constructability, low design errors
3. Decreased schedule constraints

4. Technology: Increased functionality of the design product: a computer model with associated databases.

The methodology presented in this dissertation will assist future research endeavors to evaluate new value-added aspects of engineering services.

10.3 Future Research

First there is a question regarding the scope of the Value-Bidding Model. Value-Bidding, as it is presented in this dissertation, focuses on the process of selection, i.e. steps 4 and 6 in the procurement process shown in table 10.1. However, it may benefit the analysis, or the industry as a whole, if earlier steps were analyzed. Generally, in the procurement of engineering services the project type dictates the category of engineering services the buyer requires. However, it is the author's opinion that the education process whereby the owner learns about the engineering services required for their project(s) and the nature of those services, affects the final choices of engineering firms. Earlier stages of the procurement process for engineering design services have not been fully investigated and might prove to be an area of future research.

Second, there is a need to develop a method of defining attributes and levels of the product or service under study. Recall from the case study the issues surrounding the fee attribute. As defined, (1-3%, 4-6% etc.) the levels were too broad and unrealistic. The conjoint study would be more representative of the actual decisions project managers make, if the fee levels were narrower, (i.e., 4-4.5%, 4.6-5%). Future research is needed to develop a system of evaluating attributes of a product or service and developing levels for these attributes that prove to be meaningful in the Value-Bidding studies. A preliminary attempt is made here, (Appendix A), to define attributes and potential levels for engineering design services. However, further study is warranted.

Third, there is a need to define decision criteria for evaluating the results of the Value-Bidding analysis. For instance, in Chapter 7 the author proposes that if there is a greater than average chance of success, the design firm should proceed with the proposal or at least with a more detailed analysis of the owner and competition. If the design firm has less than average chance based on the general average probability of winning, the author recommends forgoing this particular job and finding jobs where the risk is less. However, the cut-off point may vary per industry and this provides a topic of future research involving the Value-Bidding concept and model. Research is needed to develop specific decision criteria and evaluate the accuracy of the Value-Bidding analysis.

Fourth, there is the issue of applicability and accuracy. The case study conducted for this dissertation was intended to illustrate the proposed model. The case study alone does not empirically prove the validity or applicability of the Value-Bidding Model. Extensive case study research is warranted to test the Value-Bidding methodology, both in terms of industry applicability and predictive accuracy.

10.4 Conclusion

This new methodology, Value-Bidding, was developed to address the process of selling engineering service in a competitive environment. This investigation began with an analysis of the process by which engineering firms are selected (see Table 10.1). It was recognized that the selection is based on a number of attributes, including technical expertise, personnel experience, resource availability, as well as proposal price. Classical bidding theory, which evaluates the likelihood of winning based solely on bid price, was deemed insufficient for this multi-factor selection criterion. Therefore, conjoint analysis was incorporated into bidding theory to account for a quality-based selection process. To model the competitive proposal process, conjoint analysis was combined with a competitor-modeling scheme. The result of this methodology is a value-based probability of winning over a set of known, average or unknown competitors. In summary, Value-Bidding supports the:

1) Definition of services
2) Evaluation of potential competitors
3) Evaluation of the probability of winning

The resulting value-based probability of winning can be used to optimize the proposal price to support a number of business objectives, including profit maximization.

A case study was conducted to illustrate the potential predictive power of the Value-Bidding Model. In this case study, the model performed well, and functioned as an indicator of success. The Value-Bidding methodology helps engineers focus on the aspects of their services that their clients deem valuable, provides a systematic method of evaluating their competitive advantages and disadvantages, while supporting price development based on the value of their services.

References

CII, 2000, the Construction Industry Institute, Bureau of Engineering Research, College of Engineering, The University of Texas at Austin, http://construction-institute.org

Marines, Louis L, and Stuart W. Rose, (1998) State of the Profession: Adaptation of the A/E Species: an investigation into the origins and phenomena affecting the futures of architecture and engineering firms in the 21st century, Professional Services Management Association, Advanced Management Institute, and the Professional Development Resources, Inc., Raleigh, NC, 1998.

Phair, M. and Mary B. Powers, (1998) "Processing Data", Engineering News Record, McGraw-Hill, August 31, 1998.

Appendix A

Potential Attributes of Architectural and Engineering Design Services

Researchers have incorporated factors besides price into competitive bidding models for probability models as well as expert systems and artificial intelligence. Many of these factors relate to the contractor's utility and the attractiveness of the project to the contractor (Ahmad and Minkarah, 1987; Griffis, 1992; Fayek, 1998; Christodoulou, 1998). These models are contractor-centric. The models presented in this dissertation are owner-centric. The focus of the value-bidding models is on the aspects of design engineering services that influence the owner's perception of the service and the value associated with each factor.

This appendix includes some of the possible attributes of design services that may influence the owner's selection. The relative importance of different attributes will vary across architectural and engineering sectors. It is highly recommended that the user conduct preliminary studies to determine which attributes are most influential in the sector under study.

The following list contains potential attributes of engineering design services, possible levels and an indication of their potentially stochastic nature.

Attribute	*Level*	*Deterministic/ Stochastic*
Services offered in-house		
Program management	Have / do not have	Deterministic
Construction	Have / do not have	
Procurement	Have / do not have	
Equity capital	Have / do not have	
Commissioning	Have / do not have	
Operations and maintenance	Have / do not have	
Decommissioning	Have / do not have	
Firm size		
Total size (partnerships and subsidiaries	International	Deterministic
	National	
	Local	
Branch size (proposing for job)	Corporate Headquarters	Deterministic
	Regional Branch Office	
	Project Office	
Personal relationship between designer and owner	Worked several jobs, positive experience	Full range from potentially deterministic to mostly stochastic
	Worked one job, positive experience	
	Worked no previous jobs together	
	Worked one job, negative experience	
	Worked several jobs, negative experience	
Quality of proposal	High	Fairly deterministic
	Average	
	Low	
Quality of presentation	High	Fairly deterministic
	Average	
	Low	
Previous experience in technical area	Numerous jobs, high industry regard	Fairly Deterministic, potentially stochastic
	Several jobs, high industry regard	
	No related jobs	
	Several jobs, little recognition	
	Numerous jobs, little recognition	
Previous experience in geographical area	Numerous jobs, high industry regard	Fairly Deterministic, potentially stochastic
	Several jobs, high industry regard	
	No related jobs	
	Several jobs, little recognition	
	Numerous jobs, little recognition	

Previous experience with other project participants	Several jobs, positive experience	Full range from potentially deterministic to mostly stochastic
	One job, positive experience	
	No previous jobs together	
	One job, negative experience	
	Several jobs, negative experience	
Financial investment potential	Large capital investment potential	Deterministic
	Medium capital investment potential	
	Small capital investment potential	
	No capital investment potential	
Local reputation	Well known and Highly regarded	Fairly deterministic
	Slightly known and highly regarded	
	Not known	
	Slightly known and not well regarded	
	Well known and not well regarded	
Past schedule performance	Good record for on-time projects	Full range from potentially deterministic to mostly stochastic
	Fair record for on-time projects	
	Poor record for on-time projects	
	No record	
Past cost performance	High percentage of under-budget projects	Full range from potentially deterministic to mostly stochastic
	Average percentage of under-budget projects	
	No record	
	High percentage of over-budget projects	
Past quality of work performance	High Quality work, e.g. value engineering	Full range from potentially deterministic to mostly stochastic
	Average Quality work	
	Below average quality work	
	No record	
Current volume of work/work-volume capacity	Many jobs, near capacity	Full range from potentially deterministic to mostly stochastic
	Several jobs, amble capacity	
	Few jobs, excess capacity	
	No jobs	
Responsiveness	Very responsive, same day response	Full range from potentially deterministic to mostly stochastic
	Somewhat responsive, few days response	
	Not very responsive, within a week response	
	Not responsive, within a month response	
Proximity to the proposed project	In the same city, Nearby, within minutes	Deterministic
	In the same city, Close, within an hour	
	In the same city, not close, over an hour	
	In the same state	
	In the same country	
	International, half-day flight	
	International, full day flight	
	Highly experienced staff available	Fairly Stochastic

Available resources (current staff	Highly experienced staff available	
	[illegible]	
	No staff with experience available	
Specific software requirements		
Autocad	Have/ do not have	Fairly Deterministic
Microstation	Have / do not have	
In Roads	Have / do not have	
Etc.		
Technology capabilities		
2D Drafting	Have /do not have	Fairly Deterministic
2D CAD	Have /do not have	
3D Model Development	Have /do not have	
Internet Communications and Publishing	Have /do not have	
Integrated systems. (Griffis and Sturts, 2000)	Have /do not have	
Etc.		
Experience in design and development of Operations and Maintenance documents (O&M)		
For medical facilities	Yes/No	Full range from potentially deterministic to mostly stochastic
For process plants	Yes/No	
For sewage treatment plants	Yes/No	
For energy plants	Yes/No	
Etc.		
Educational qualifications of staff		
Licensed Engineer	Yes/No	
Licensed Architect	Yes/No	
Ph.D.	Yes/No	
Law	Yes/No	
Past Public Work		
Federal	Yes/No	
State	Yes/No	
Local	Yes/No	

Specialization		
Administrative	Primary service	Fairly Deterministic
	Major division	
	Few personnel on staff	
	Do not offer in-house	
Architectural	4 levels, see Admin. above	
Chemical Engineering	4 levels, see Admin. above	
Civil Engineering	4 levels, see Admin. above	
Construction Inspection	4 levels, see Admin. above	
Draftspersons	4 levels	
Ecologists	4 levels	
Economists	4 levels, see Admin. above	
Electrical Engineers	4 levels	
Estimators	4 levels	
Geologists	4 levels	
Hydrologists	4 levels, see Admin. above	
Interior Designers	4 levels	
Landscape Architects	4 levels	
Mechanical Engineers	4 levels, see Admin. above	
Mining Engineers	4 levels	
Oceanographers	4 levels	
Planners: Urban/Regional	4 levels, see Admin. above	
Sanitary Engineers	4 levels	
Soils Engineers	4 levels	
Specification Writers	4 levels, see Admin. above	
Structural Engineers	4 levels	
Surveyors	4 levels	
Transportation Engineers	4 levels, see Admin. above	

Table A.1 Potential Conjoint Attributes and Levels

References

Ahmad, I., and I. Minkarah, (1987) "An Additive Utility Model for Selecting Optimum Bid Price." Proceedings: 18th Annual Pittsburgh Conference on Modelling and Simulation, 18(1), pg. 367-373.

Christodoulou, Symeon, (1998) "Optimum Bid Markup Calculation in Competitive Bidding Environments using Fuzzy Artificial Neural Networks," Ph.D. Thesis, Columbia University, New York City, New York.

Fayek, Aminah, (1998) "Competitive Bidding Strategy Model and Software System for Bid Preparation." Journal of Construction Engineering and Management, Vol. 204 , No.1, January/February, 1998, pg. 1-10.

Griffis, F.H.(Bud), (1992) "Bidding Strategy: Winning Over Key Competitors", Journal of Construction Engineering and Management, Vol. 118, No. 1, March, 1992, pg. 151-165.

Appendix B

Potential Sources of Information Regarding Competitors

American Consulting Engineering Council
http://www.acec.org

Firm name
Firm address
# of employees
ownership
minority status
firm corporate range (international, nation, local)
company website

American Architecture
http://www.americanarchitecture.com

Name
Address
Phone number
Progressive listings optional: e-mail, webpage, description

AIA (Architectural Institute of America)
http://www.aiaonline.org

Firm name
Firm address
Year established
Firm size (quality)
Firm personnel by discipline
Example projects
Type of work

Architects USA
http://www.architectsusa.com

name
address
phone number
web pages and information on featured firms
Type of information for featured firms:
    Size of Firm
    Types of work
    Additional Services

The Architectural Review
http://www.arplus.com/home.htm

listings: name. address. phone. e-mail. and webpage if available.

http://www.arplus.com/competition/frame.htm

listings of architectural awards

The Blue Book
http://www.thebluebook.com

Firm name
Firm Address
Firm phone/fax
Contact person
Year established
Web page
Blue Book Classification (ex.)
Manufacture's Certifications
Company Description
Recent Projects
Trade Associations

Building, Design and Construction
http://www.bdc.com

Building Trades Directors
http://www.buildingtradesdir.com

name
address
phone number
optional links to websites and other information

Commerce Business Daily
http://www.ld.com/cbd/today/

reports contract awards

Construction Net
http://search.constructionnet.net

Design Share
http://www.designshare.com/

Name
Location
Services, specialties
Web site

DOD's Database
http://www.ccr.dlsc.dla.mil

Firm name
Firm address
Corporate statuses
Business type
Goods and Services

Eastern Contractors Association
http://www.easterncontractorsassn.org/

Name
Address
Phone & Fax

http://www.easterncontractorsassn.org/benefits.html

offers services to members such as: **PLAN ROOM**

The Plan Room is available for membership usage and is one of the most comprehensive in New York State. Bid documents, specifications and blueprints may be used 8 a.m. to 5 p.m. as well as being signed out overnight and on weekends.

Engineering News Record
http://www.enr.com/

Hoovers On-line
http://www.hoovers.com

Information on public companies, litigation, competitors, etc.

New York Association of Consulting Engineers, Inc.
http://www.cecnys.org/memberoster.htm

Name
Address
Phone & Fax
E-mail
Web site (if possible)
Description of services

New York Property
http://www.nyproperty.com

Real Estate Journal Interactive
http://www.reji.com

Find information on past jobs and specific designers.

School Building Association
http://www.cefpi.org/

Area of Specialization
Personal Statement
Name of Firm:
Contact Person(s):
Address:
Phone:
Fax:
E-mail:
WWW:
Service Type
Local/National/International

Thomas Register for American Manufacturers
www.thomasregister.com

Listings per industry type
Contact info. and website if available.

U.S. Green Buildings Council
http://www.usgbc.org/

members list with website link

Other Possible Links:
http://LinkLane.com
http://Yahoo.com
http://phone-soft.com
http://www.oingo.com
http://www.homequest.net/
http://www.dbbonline.com (design build business)
http://www.lybot.com
http://www.vitruvio.ch
http://www.nyclink.org/

Trade Papers are available for purchase on-line:
http://www.netstoreusa.com/arbooks/

Appendix C

Case Study: Conjoint Analysis, Example Survey

Welcome
University Program Management Group
Case study: Engineering Design Firm Selection

conducted by Carrie Sturts
Department of Civil Engineering, Columbia University

Hello,

Thank you for taking this quick survey (10 minutes). We are studying the importance of different factors (e.g., experience, personal relationship, and price) in the selection process for architectural and engineering design services. The following questions are a simulation of a proposal process. Based on the factors presented, please choose the design firm you would most prefer. Please imagine that these fictional firms are the only ones in the market, and firms you are familiar with in the real world are not available in this simulated selection process. Your honest and thoughtful feedback is most appreciated. Any problems, comments or questions, please ask.

Thanks!

Carrie

Preliminary Question

Factors in the choice of Architectural and Engineering Design Services

If you were to chose 4 or 5 factors that are the most important in the selection process for engineering design services, what would those factors be (in order of importance)? (For example, price, job experience, personnel technical expertise, geographic location, etc.)

1)

2)

3)

4)

5)

Comments:

In the following study, there are three factors to consider in your selection of a design firm:

Previous work with design firm
Levels:
several jobs, ***positive*** experience
one job, ***positive*** experience
no previous jobs
one job, ***negative*** experience
several jobs, ***negative*** experience

This attribute describes the number of jobs this design firm has done with you (the owner) and whether that experience was mostly positive or mostly negative for you, the owner.

Experience of firm and of key personnel.
Firms include corporate resumes as well as individual resumes for key personnel assigned to the project. This attribute describes the type of jobs presented in these resumes:

levels:
Firm experience : ***no*** similar jobs
Key Personnel experience : ***no*** similar jobs
Firm experience : ***one*** similar job
Key personnel experience : ***no*** similar jobs
Firm experience : ***many*** similar jobs
Key Personnel: ***no*** similar jobs
Firm experience : ***no*** similar jobs
Key Personnel: ***many*** similar jobs
Firm experience : ***one*** similar job
Key Personnel: ***many*** similar jobs
Firm experience : ***many*** similar jobs
Key Personnel: ***many*** similar jobs

This refers to the job TYPE, not overall engineering experience. This attributes describes the job experience of both 1) the firm, and 2) the key personnel. No similar jobs refers to the fact that there are no similar jobs in corporate or personal history, one similar job conveys the fact that there is one job in the corporate history, and many similar jobs conveys the fact that there are the firm or personnel have a lot of experience in the type of job they are proposing for.

For example, a firm might have worked on many hospital jobs in the past, but they have not worked for a university before. They would have no similar jobs in corporate experience for university construction. (but, they are still very qualified engineers, technically speaking)

Price (% of Total Project Cost)

levels:
1-3 % of total job cost
4-6 % of total job cost
7-9 % of total job cost
10-12% of total job cost
13-15% of total job cost

This attributes is the price of the engineering service in percent of total installed cost. For example, if the total project cost is 1 million dollars, the design fee would be a) $10,000 - $30,000, b) $40,000 - $60,000, etc.

For the next 10 questions, please choose one design firm per question page, based on the attribute descriptions.

Thank you very much for your input!

Question 1

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

Question 2

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **SEVERAL** previous jobs, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE** similar job

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **13-15** % job cost
CHECK BOX ☐

Question 3

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **13-15** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **ONE** previous job, **POSITIVE** Experience

(Experience of firm and of key personnel) Firm experience: **ONE** similar job

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost
CHECK BOX ☐

Question 4

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **13-15** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **SEVERAL** previous jobs, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost
CHECK BOX ☐

Question 5

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

Question 6

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **SEVERAL** previous jobs, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE** similar job

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost

CHECK BOX ☐

FIRM B

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost

CHECK BOX ☐

FIRM C

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **ONE** similar job

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost

CHECK BOX ☐

Question 7

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **SEVERAL** previous jobs, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **7-9** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **ONE** previous job, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

Question 8

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **13-15** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE** similar job

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost
CHECK BOX ☐

Question 9

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **13-15** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost
CHECK BOX ☐

Question 10

Which proposal would you choose for your next project?
(Please chose **ONLY ONE** firm)

FIRM A

(Previous work with design firm) **ONE** previous job, **NEGATIVE** experience

(Experience of firm and of key personnel) Firm experience: **ONE similar job**

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **4-6** % job cost
CHECK BOX ☐

FIRM B

(Previous work with design firm) **SEVERAL** previous jobs, **POSITIVE** experience

(Experience of firm and of key personnel) Firm experience: **MANY** similar jobs

key personnel experience: **NO** similar jobs

Price (% of Total Project Cost) fee = **1-3** % job cost
CHECK BOX ☐

FIRM C

(Previous work with design firm) **NO** previous jobs

(Experience of firm and of key personnel) Firm experience: **NO** similar jobs

key personnel experience: **MANY** similar jobs

Price (% of Total Project Cost) fee = **10-12** % job cost
CHECK BOX ☐

Follow-up Question

Does this simulation represent the real decisions you make when choosing an architecture or engineering design firm?

❒ Yes, this exactly represents the decision process

❒ Yes, these are the main factors in the decision process

❒ Kind of, these are only a few of the factors in the decision process

❒ No, these are not the factors in the decision process

❒ No, you cannot model the decision process like this

Thank you very much for your time!
Carrie Sturts

Appendix D

Matlab Computer Code for Value-Bidding Analysis

This appendix includes the entire computer code used in Chapter 9 as well as an explanation. The notes are designated with a line beginning with the symbol "%".

This computer code is generalized to handle from 2 to 6 competitors. It is currently set up with three attributes, just as in the case study, but can be modified to handle any number of attributes. The utility vector and the probability of existence matrices both reflect this number of attributes.

```
clear

%first we load in the utility values

%Attribute Utility Vectors

U=[3.4,1.3,0.0,-1.4,-3.3];
V=[-2.5,-2.2,0.3,1.0,3.4];
W=[1.6, 0.5,0.2,-0.6,-1.7];
n=1;

%U, V and W stand for attributes 1, 2 and 3 respectively.  These
%numbers are the utility values from the conjoint analysis.

[x,u]=size(U);
[y,v]=size(V);
[z,w]=size(W);


%Calculating Profile utilities, this loop operation calculates the
%utility for every possible combination of attributes, regardless if
%they exist for this case or not.

for i=1:u
   for j=1:v
      for k=1:w

         Util(n)=U(i)+V(j)+W(k);
         n=n+1;
      end
   end
end

%-----------------------------------------------

fprintf('running ProbExist\n');
```

```
% this section generates the probability of existence matrix for each
% competitor

%The probability distributes are places in a text file, i.e.,
%P39_1.txt. This text file contains the distribution in columns
%representing each competitor. This computer code will estimate the
%probability of the firm in column one, as compared to the firms in
%columns 2, 3 … and so forth. File P39_1 contains the probabilities
%for attribute one, file P39_2 contains the probabilities for attribute
%two and so forth. To add more attributes, one need only add more
%files.


load P39_1.txt
load P39_2.txt
load P39_3.txt

Pave1=P39_1;
Pave2=P39_2;
Pave3=P39_3;

[R1,C1]=size(Pave1);
[R2,C2]=size(Pave2);
[R3,C3]=size(Pave3);



%build P(existence) matrix

for c=1:C1;
n=1;
    for i=1:R1
        for j=1:R2
            for k=1:R3
                Pexist(n,c)=Pave1(i,c)*Pave2(j,c)*Pave3(k,c);
                n=n+1;
            end
        end
    end
end


%-----------------------
```

%The next section is the body of the code.

```
%dimentions of probability array

[RP,CP]=size(Pexist);

fprintf('done. CP=%d\n', CP);
```

```
%To save computation run time, this section eliminates the utilities
%and probabilities that will NOT be used.  The result is separate
%utility matrices for each competitor.


newA=1;
newB=1;
newC=1;
newD=1;
newE=1;
newF=1;

for row=1:RP

   Pcolumn=1;
   if Pexist(row,Pcolumn)==0
   else
      UtilA(newA)=Util(row);
      PA(newA)=Pexist(row,Pcolumn);
      newA=newA+1;
   end

   if CP>=2
      Pcolumn=2;
      if Pexist(row,Pcolumn)==0
      else
         UtilB(newB)=Util(row);
         PB(newB)=Pexist(row,Pcolumn);
         newB=newB+1;
      end
   end

   if CP>=3
      Pcolumn=3;
      if Pexist(row,Pcolumn)==0
      else
         UtilC(newC)=Util(row);
         PC(newC)=Pexist(row,Pcolumn);
         newC=newC+1;
      end
   end

   if CP>=4
      Pcolumn=4;
      if Pexist(row,Pcolumn)==0
      else
         UtilD(newD)=Util(row);
         PD(newD)=Pexist(row,Pcolumn);
         newD=newD+1;
      end
   end

   if CP>=5
      Pcolumn=5;
      if Pexist(row,Pcolumn)==0
      else
         UtilE(newE)=Util(row);
```

```
            PE(newE)=Pexist(row,Pcolumn);
            newE=newE+1;
         end
      end

      if CP>=6
         Pcolumn=6;
         if Pexist(row,Pcolumn)==0
         else
            UtilF(newF)=Util(row);
            PF(newF)=Pexist(row,Pcolumn);
            newF=newF+1;
         end
      end

end


%Calculating the probability of winning :
%Prob(A win/B)=exp(U(A))/exp(U(A)+U(B)) times the probability of
%existence.  This section calculates the probability of Firm A winning,
%given the other competitors, B, C, D, E & F.  If there are only two
%competitors, then there will only be A and B.


[rowA,sizeA]=size(UtilA)
if CP>=2
   [rowB,sizeB]=size(UtilB)
end
if CP>=3
   [rowC,sizeC]=size(UtilC)
end
if CP>=4
   [rowD,sizeD]=size(UtilD)
end
if CP>=5
   [rowE,sizeE]=size(UtilE)
end

if CP>=6
   [rowF,sizeF]=size(UtilF)
end

pause

%calculation for 2 competitors

if CP==2
   for Acounter=1:sizeA,
      Ncounter=1;
      for Bcounter=1:sizeB,
         fprintf('Acounter=%d, Bcounter=%d\n', Acounter, Bcounter);

CompareA(Acounter,Ncounter)=(exp(UtilA(Acounter))/(exp(UtilA(Acounter))
+exp(UtilB(Bcounter))))*PA(Acounter)*PB(Bcounter);
         Ncounter=Ncounter+1;
      end
```

```
      end
   end


   %calculation for 3 competitors

   if CP==3
      for Acounter=1:sizeA
         Ncounter=1;
         for Bcounter=1:sizeB
            fprintf('Acounter=%d, Bcounter=%d\n', Acounter, Bcounter);
            for Ccounter=1:sizeC

   CompareA(Acounter,Ncounter)=(exp(UtilA(Acounter))/(exp(UtilA(Acounter))
   +exp(UtilB(Bcounter))+exp(UtilC(Ccounter))))*PA(Acounter)*PB(Bcounter)*
   PC(Ccounter);
                  Ncounter=Ncounter+1;
               end
            end
      end
   end

   %calculation for 4 competitors
   if CP==4
      for Acounter=1:sizeA
         Ncounter=1;
         for Bcounter=1:sizeB
            fprintf('Acounter=%d, Bcounter=%d\n', Acounter, Bcounter);
            for Ccounter=1:sizeC
               for Dcounter=1:sizeD

   CompareA(Acounter,Ncounter)=(exp(UtilA(Acounter))/(exp(UtilA(Acounter))
   +exp(UtilB(Bcounter))+exp(UtilC(Ccounter))+exp(UtilD(Dcounter))))*PA(Ac
   ounter)*PB(Bcounter)*PC(Ccounter)*PD(Dcounter);
                     Ncounter=Ncounter+1;
                  end
               end
            end
      end
   end

   %calculation for 5 competitors
   if CP==5
      for Acounter=1:sizeA
         Ncounter=1;
         for Bcounter=1:sizeB
            fprintf('Acounter=%d, Bcounter=%d\n', Acounter, Bcounter);
            for Ccounter=1:sizeC
               for Dcounter=1:sizeD
                  for Ecounter=1:sizeE

   CompareA(Acounter,Ncounter)=(exp(UtilA(Acounter))/(exp(UtilA(Acounter))
   +exp(UtilB(Bcounter))+exp(UtilC(Ccounter))+exp(UtilD(Dcounter))+exp(Uti
   lE(Ecounter))))*PA(Acounter)*PB(Bcounter)*PC(Ccounter)*PD(Dcounter)*PE(
   Ecounter);
                        Ncounter=Ncounter+1;
                     end
```

```
                end
            end
        end
    end
end

%calculation for 6 competitors
if CP==6
    for Acounter=1:sizeA
        Ncounter=1;
        for Bcounter=1:sizeB
            fprintf('Acounter=%d, Bcounter=%d\n', Acounter, Bcounter);
            for Ccounter=1:sizeC
                for Dcounter=1:sizeD
                    for Ecounter=1:sizeE
                        for Fcounter=1:sizeF

CompareA(Acounter,Ncounter)=(exp(UtilA(Acounter))/(exp(UtilA(Acounter))
+exp(UtilB(Bcounter))+exp(UtilC(Ccounter))+exp(UtilD(Dcounter))+exp(Uti
lE(Ecounter))+exp(UtilF(Fcounter))))*PA(Acounter)*PB(Bcounter)*PC(Ccoun
ter)*PD(Dcounter)*PE(Ecounter)*PF(Fcounter);
                            Ncounter=Ncounter+1;
                        end
                    end
                end
            end
        end
    end
end


Ncounter=Ncounter-1;



%Sum rows of CompareA to obtain the probabilities of competitor A's
%Possible profiles winning

SUM(sizeA)=zeros;

for Acounter=1:sizeA
    for Mcounter=1:Ncounter
        SUM(Acounter)=SUM(Acounter)+CompareA(Acounter,Mcounter);
    end
end

save run39A SUM Pexist
```

%SUM is a vector which contains as many entries as there are possible combinations of Firm A's attributes. For example, if Firm A has the following probability of existence profile:

Attribute 1	
Level 1	0
Level 2	.50
Level 3	.25
Level 4	0
Level 5	.25
Attribute 2	
Level 1	0
Level 2	.50
Level 3	.50
Level 4	0

Table D.1 Example probability of existence for illustrative purposes

There are 6 possible combinations that make up Firm A.

	Attribute 1	Attribute 2	Probability of existence
Combination 1	Level 2	Level 2	.250
Combination 2	Level 2	Level 3	.250
Combination 3	Level 3	Level 2	.125
Combination 4	Level 3	Level 3	.125
Combination 5	Level 4	Level 2	.125
Combination 6	Level 4	Level 3	.125

Table D.2 Example Probability of Profile Existence Development

The SUM variable lists the probabilities of winning for each possible combination. Therefore, SUM(1) = Probability of winning of Combination 1. SUM(2) = Probability of winning of Combination 2, and so forth. In this way, one can compare variations in levels to observe the effects of combinations on the probability of winning. One can also estimate the probability of competitors winning, given uncertainty (probability distributions and multiple possible profiles.)

To get an over all probability of winning, one can sum the elements in the SUM variable. For example:

```
TotalSum = 0;

for I=1:sizeA
        TotalSum=SUM(i) + TotalSum;
end
```