A PROJECT DELIVERY SELECTION SYSTEM

by

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ABSTRACT

This thesis presents a Project Delivery Selection System [PDSS] which prescribes a method to select a project delivery system based on job requirements. The PDSS accounts for a project's critical risk factors and recommends a project organizational structure and contract strategy for various project situations.

The model, a decision tree, was developed from an application of rules and intuition. The rules, in the form of decision tables, were developed from a review of the current literature on project delivery and from interviewing experts in this field. In certain instances the rules were unclear or provided no clear cut answer. It was, therefore, necessary to make estimates as to which rule was most applicable. The model development process included a review of the literature and expert interviews. The former helped in providing a listing of the project risk factors while the latter provided guidance as to which ones were most critical. The experts also provided information as to the impact of these critical risk factors on the selection of a particular organizational structure and contract strategy.

The model was tested on 22 projects with a wide range of project characteristics. The purpose of the testing was to determine if the selection of the project team and contract strategy, using the PDSS, corresponded with that actually chosen by the project team, and whether this had an impact on project success or failure. The tested projects had a wide range of project risk factors and many different organizational structures and contract strategies. It proved to be accurate for many different project situations.

The primary application of this research is that an owner can use the model to select a project organizational structure and contract strategy, both important project delivery decisions, and therefore, increase the chances of job success.
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GLOSSARY OF TERMS

Above Standard: A risk factor choice that refers to the specified quality level being higher than industry standard for the current project.

Competitive Contracts: A method of award contract classification that describes contracts prepared on a fixed-price basis. This classification of contracts includes unit-price or lump sum contracts.

Construction Management [G.M.P]: A Project Organizational Structure sometimes referred to as "constructor" construction management. At some point during design the construction management agreement is modified to include a guaranteed maximum price for construction. Once the GMP is established the construction manager is placed in the dual role of construction manager and constructor. Construction contracts can be held by either the GMP management personnel or the owner.

Complexity: A project risk factor and part of "job characteristics" risk that refers to the degree of difficulty of the project.

Consortium for the Advancement of the Building Sciences (CABS): A partnership between Penn State and firms focusing on advancing the state of the art in the building industry.

Construction Management [Agency]: A Project Organizational Structure that is sometimes referred to as "pure" construction management because of the fiduciary relationship between the owner and the construction manager throughout project delivery. All contracts for design, construction, and construction-support services are held by the owner. The C.M. works as part of the construction team with the owner, designer, and constructor but does not
become involved in providing any of the services the other team members perform.

Contract: "Agreement between two or more people to do something, especially set forth in writing and enforceable by law" Webster (1988).

Contract Types: The set of possible project agreements falling into two broad categories: Fixed-Price and Cost-Reimbursable.

Contracting Strategy: The third activity of the PDSS. It is the process used in selecting a particular contract type.

Cost: A project risk factor that describes the dollar amount specified for project completion. It is either "critical" or "not critical."

Cost Plus Fixed Fee: A Cost-Reimbursable contract in which a constructor is reimbursed for his project costs plus an agreed upon fee.

Cost Plus Fixed Fee with Guaranteed Maximum Cost: A Cost-Reimbursable contract often referred to as a Guaranteed Maximum Price contract (GMP). In this type contract the constructor guarantees that the total contract price will not exceed the specified amount. It adds some of the risk of a fixed price contract and as such it is expected that the constructor's fee will include a contingency for his risk assumption.

Cost Plus Incentive Fee: A Cost-Reimbursable contract that is designed to provide an incentive for reducing project cost. A constructor's target fee is increased or decreased according to the final project cost. He receives an increased fee if he is able to complete the project under the original estimate.

Cost Plus Percentage of Cost: A Cost-Reimbursable contract that pays the constructor a fee that is a percentage of the actual project cost. Because it provides no incentive for a constructor to reduce costs this type contract may not be used by U.S. government agencies.
Cost Reimbursable Contracts: A category of contract types where the work is to be performed in accordance with terms as negotiated between the parties. Several types exist.

Critical Project Success Factors (CPSF): The project factors deemed essential for project success. The four factors are: the facility team, the contract, facility experience, and optimization information.

CPSF Projects : Projects used in the study of the same name. Pairs of projects were evaluated to determine the factors leading to job success. A project pair is comprised of two similar projects, one successful and one unsuccessful.

Critical: A project risk factor choice that describes the risk factor as being decisive or very important.

Design-Build: A Project Organizational Structure involving two parties, the owner and the design-builder. The designer has no contractual obligation to the owner. The design-builder provides design and construction management services in-house or contracts for these services from other firms. It is also common that the designer, constructor, and speciality constructors form a consortium as one corporate entity or one joint venture.

Design Manage: A Project Organizational Structure where construction is performed by a number of independent contractors and managed by a construction manager.

Expert Projects: Projects used in the development of the Project Delivery Selection System (PDSS). Experts in the project delivery field were asked questions on a pair of projects. A pair is comprised of one successful and one unsuccessful project.
Fixed Price Contracts: A category of contract types that refers to competitively bid contracts. The contracting party agrees to perform the work for a fixed sum of money.

Fixed Price with Escalation: A Fixed-Price contract type in which the contract value is adjusted according to a specified price index. Typically, these could be used during periods of high inflation. During high inflationary periods a constructor may add a large contingency amount if such a provision is not provided.

Industry Standard: A risk factor choice that refers to the specified quality level equalling what is expected for the current project.

Integrated Building Process Model (IBPM): A model describing the processes required to provide a facility over its life. The functions comprising the IBPM include: Manage Facility, Plan Facility, Design Facility, Construct Facility, and Operate Facility.

Job Characteristics: A project risk factor made up of two elements, project scope and project complexity.

Lump Sum: A Fixed-Price contract type that provides a defined payment for work specified in the contract. The quantities of material are estimated by the constructor who submits a single fixed price for the completed project.

Multiple Prime: A Project Organizational Structure variation where an owner or his construction manager contracts with several contractors to perform distinct phases of the project. It is also known as "Separate Bid Packages."

Negotiated Contracts: A method of award contract classification where the owner reimburses the worker for all incurred costs plus an additional fee for overhead and profit.
Negotiated Guaranteed Maximum Price: A Cost-Reimbursable contract type in which the owner and general contractor are committed, from the beginning, to reach an agreement on a guaranteed maximum price for the cost of construction. The estimate of cost upon which the GMP is based usually requires that design be about 50% complete and the specifications at least 80% complete.

Not Critical: A project risk factor choice describing a situation which is important but not to a degree that it is critical.

Of the Essence: A project risk factor choice referring to the project risk factor, time. Of the Essence describes a situation which is very important or critical.

Owner Construction: A Project Organizational Structure where the owner's staff designs the project and provides construction administration. This approach differs from the others in that the owner does not rely on outside assistance for design or construction services. On some projects, there is more than one prime constructor.

Owner Experience: A project risk factor that describes the level of expertise of the owner or his hired agent with the requirements of the current project.

Project Delivery System (PDS): Describes the organizational framework, contractual obligations and payment terms for the players. It comprises a project organizational structure and a contract strategy for a given project.

PDSS Functions: Describes the activities that need to be accomplished in selecting a project delivery system. The three activities include: collect data to determine the project risks, select the project organizational team, and select the project contract strategy.

Quality: A project risk factor, defined as industry standard or above, that refers to the features, described by the plans and specifications, comprising a building.
Scope: A project risk factor that describes the degree of definition or "what" of a project. The more important of the two elements comprising the "job characteristics" risk factor.

Size: A project risk factor that describes the dimensions or magnitude of a building.

Team Experience: A project risk factor that describes the level of expertise of the other team members, less the owner, with the technology for the current project. The team is either "experienced" or "inexperienced."

Time: A project risk factor that describes the project duration or schedule. Time is either critical (of the essence) or not critical (not of the essence).

Traditional: A Project Organizational Structure that involving three parties: the owner, designer, and constructor. This approach is characterized by a sequential execution of the delivery phases—planning, design, award/advertise, construction, and occupancy.

Turnkey: A Project Organizational Structure where the owner contracts with a single firm to plan, implement, and control the entire project through completion. The turnkey firm must provide design and construction management services in house or contract with other firms for these services. Two approaches are cited: the Design-Build and the Design-Manage approaches.

Unit Price: A Fixed-Price contract that specifies the amount to be paid for each given work unit. The work units are measured in the field upon completion of the project.
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CHAPTER 1

INTRODUCTION

As recent as the late 1970's, the traditional approach (see Glossary) was the predominant project delivery system. Today's industry, however, is characterized by larger, more complex projects, performed under increasingly greater time pressures. Consequently, other project delivery systems have become necessary and have evolved to meet this need. These include the design-build, construction management, and owner constructed approaches.

Given the plethora of available systems facing an owner, which one should be chosen and when? Consider two different projects, a hospital and a parking garage. Given the different risks associated with each project, is one delivery system more appropriate than another? Does one system increase the chances of project success? Does one system increase the chances of project failure? This report sheds light on these questions. The Project Delivery Selection System (PDSS), presented in this report, accounts for differing project risks and recommends a project organizational structure and contract strategy for each unique project.

1.1 PROBLEM BACKGROUND

Recently, a large experienced owner contracted to build a highly complex, 71,000 ft², multi-use facility. Total project cost was budgeted at $8 million with a project duration of 30 months. The project scope was poorly defined and it was critical that completion time be met in order to comply with prior commitments. The owner
chose to organize the project team under the Traditional organizational structure. Payment terms were made under a Fixed-Price Lump Sum arrangement.

Problems developed early between all parties. The owner wanted a functional building, the architect wanted a "monument," while the constructors were too inexperienced to provide either. Numerous change orders arose and relations were strained as the project fell farther behind schedule and over budget. Significant problems arose with the building's mechanical and electrical systems. The end result was a project which was $2 million over budget, 5 months behind schedule, and which failed to meet the specified quality requirements.

Another experienced owner contracted to build a similar type project under essentially the same conditions. This time, however, the owner selected the Construction Management (Agency) organizational structure with Lump Sum payment terms. This project was within budget, on time, and met the specified quality requirements.

Given two similar type projects, why was one successful and the other unsuccessful? Is it possible that the selection of the team and/or contract strategy has a direct impact on project success/failure? This research attempts to answer these questions.

1.2 PROBLEM STATEMENT

Each job is unique. In addition to differing job requirements, owner capabilities and local construction expertise also differ. There is an industry need to prescribe a method to select an organizational structure and contract strategy based on the project requirements, risks, and potential team player's expertise. This research develops a Project Delivery Selection System as one such mechanism, which when used by an
owner in the selection process, could prevent undesirable situations as the one previously described.

1.3 RESEARCH OBJECTIVES

To address the stated problem, three objectives are proposed. They are:

1. To identify the most critical project risk factors and their impacts on the project organizational structure and contract strategy.

2. To provide a method/model that an owner could use to select a project delivery system for a given project. This delivery system would include a project organizational structure, and a project contracting strategy.

3. To test the model on projects.

1.4 RESEARCH SIGNIFICANCE

The value of this thesis is that it:

1. Provides a method an owner could use to make important project delivery selection decisions.

2. Provides a listing of the critical project risk factors.

3. Defines and lists project organizational structures and contract strategies.

4. Provides decision tables to evaluate appropriate structures/strategies given differing project risk factors.

5. Provides a decision tree that recommends a project organizational structure and contract strategy for a given project.
1.5 METHODOLOGY

The following methodology was used to meet the objectives of the study.

1.5.1 Literature Review

The literature was reviewed to evaluate project risks and their impact on the selection of an organizational structure and contract strategy. The literature was also used to identify the differing project organizational structures and contract strategies. The end result of the literature review is a set of decision tables which identify the most appropriate project organizational structure and contract strategy for each critical job risk factor.

1.5.2 Data Collection

Seven experts in selecting project delivery systems were interviewed to determine project risks and selection criteria for a project delivery approach and contract strategy. Six experts came from companies who belong to the Consortium for the Advancement of the Building Sciences [CABS], and one was an independent consultant. They include owners, architects, and constructors. The interview process began with the experts filling out a questionnaire [see Appendix A]. Followup face to face interviews and/or phone interviews were conducted to clarify answers and to ensure completeness of the questionnaire. These interviews lasted, on average, four hours per respondent.

Data was reduced to a set of decision tables illustrating expert opinions of the most appropriate organizational structures and contract strategies for different project conditions. The data was then analyzed and rules developed for the selection of an organizational structure and contract strategy. A listing of the critical project risk factors resulted.
1.5.3 PDSS Model Development

The PDSS model was developed from an application of rules and the authors' judgment. The rules were obtained from both the literature review and expert interviews. The author had to use his own reasoning in cases were the literature was silent or the experts had no preference. In forming the model it was necessary to obtain a listing of the critical project risk factors and the relative importance of each. Next, through the application of rules and estimates the respective organizational structure and contract strategy models were developed. The end result is a model which recommends an organizational structure and contract strategy for combinations of the critical project risk factors.

1.5.4 Model Testing

A total of 11 pairs (22 projects) of successful/unsuccessful projects were used to test the data. Projects ranged from classroom/office buildings to hospitals to laboratory facilities and were generally in the 100,000-300,000 ft² range. Fourteen projects were provided by the experts and eight by CABS members. The resulting model was tested to determine if the success or failure of a project could be attributed to the proper or improper project delivery selection process.

1.6 LIMITATIONS

The intent of the research is to provide a model/set of rules an owner or his representative could use in making project delivery selection decisions. As such if there is a bias, it is at the expense of the contractors, towards the owner's viewpoint. The model (decision trees) asks for "yes/no" answers in terms of the project risk factors. A project is easy or hard; the team is experienced or inexperienced; time is of the essence or it is not of the essence. The model does not incorporate "average" or
"medium" situations. On the other hand, however, the model decision tables do consider these different degrees of risk by ranking solutions. While the model recommends an organizational structure and contract strategy for different project risks, it does not describe the interrelationships between, nor quantify, the risk factors. It is also virtually impossible to account for all the risks that are found on projects. Model users need to first properly evaluate the job risks and determine if the model considers the risks on the given projects.

1.7 SUMMARY AND THESIS OUTLINE

This chapter provided an introduction to the research objectives and methodology. It identified project delivery as a major decision facing owners: i.e., the systematic selection of the proper organizational structure and contract strategy for each unique project.

Chapter 2 provides a summary of the literature relating to the study. It identifies project risks and the impacts on the PDSS. Organizational structures and contract strategies are reviewed. Models which identify the most appropriate organizational structure and contract strategy for different project conditions are presented.

In Chapter 3, the data collection process is described and expert models are presented. Chapter 4 presents the PDSS model and Chapter 5 analyzes the results of the testing procedure. Lastly, Chapter 6 summarizes the study, identifies limitations of the PDSS, and suggests areas for further research.
CHAPTER 2

LITERATURE REVIEW

This chapter defines the elements that make up a project delivery system and explains where project delivery fits into the overall life cycle of a building. The key project risk elements, existing project organizational structures, and contract strategies are defined in detail. Rules, in the form of decision tables, are then presented to identify the appropriate organizational structure and contract strategy given different risk factors.

2.1 PROJECT DELIVERY AND ITS ELEMENTS

A Project Delivery System describes the organizational framework, contractual obligations and payment terms for the players. It comprises a project organizational structure and a contract strategy for a given project. Project risk is an element that heavily influences the selection of a delivery system. As a result, proper evaluation of the risks are essential for selecting a good project delivery system.

This section will define the elements comprising the Project Delivery System. They include:

1. Project risk evaluation.
2. Project organizational structures, and
3. Project contract strategies.

Risk is common to all construction projects. Several definitions of project risk are:

* "The potential for loss or injury." Webster (1988)
• "Failure to obtain all, or even any, of the anticipated benefits." McFarlan (1981)

• "The reduction of uncertainty as a project moves from its inception to completion." Howell (1991)

".. the probability that an unfavorable outcome will occur" or the set of potential unfavorable outcomes associated with uncertainty. (Neil 1989)

Diekmann also distinguishes between risk, certainty, and uncertainty. Risk describes a situation where some elements of the decision are variable but the degree of variability can be predicted in probabilistic terms. For the purpose of this research, risk is defined as any element which affects a project's outcome.

The definitions of project risk are as varied as the opinions on the value of a proper project risk assessment. McFarlan (1981) believes individuals rarely deal frankly with the risk of slippage in time, cost overrun, or outright failure: "Rather, they deny the existence of such possibilities by ignoring them. They assume the appropriate human skills, controls, and so on that will ensure success" (p.143).

Project organizational structures describe the relationships between all the players required to provide the facility. The players include the owner, architect/engineer, construction manager, constructor, and prime contractors. They can be organized in various ways to deliver a construction project and are affected differently depending on the selected structure. There are slight differences among the various sources in terms of types of organizational structures.

The contract, as defined by Webster (1988), "is the agreement between two or more people to do something, especially set forth in writing and enforceable by law."

"The goal of the contracting process is to provide a series of contracts that allows and encourages the various players to behave as a cohesive team without conflicts of interest and differing goals" (Sanvido, 1990b, p.143). Neil (1989) believes that
successful contracts have at least one common characteristic: Thoughtful and thorough preparation by the owner before the contract is let. There are several contract types. Contracting strategy, then, refers to the manner in which a particular contract is selected.

2.2 PROJECT DELIVERY AND THE LIFE CYCLE OF A BUILDING

This section discusses project delivery in terms of the overall facility life cycle. The key phases in the life of a facility are defined by the Integrated Building Process Model as, Manage Facility, Plan Facility, Design Facility, Construct Facility, and Operate Facility (Sanvido, 1990a). All of these functions are performed for a given project type by a facility team comprised of an owner, designer, constructor, and operator. These team members are arranged in an organization and their roles and responsibilities are defined by the contract.

Two key decisions are essential to the management of this process. The first is the structure of the team that will provide the facility and the second is the contract type selected to allocate risk and describe the behavior of this team. The selection of the organization form and contracts are called the project delivery elements, and are selected in the second life cycle function, Plan Facility. They are represented in the project execution plan, an output of the Plan Facility function. Plan Facility "encompasses all the functions required to define the owners needs and the methods to achieve these. These activities translate the facility idea into a program for design, a project execution plan (PEP), and a site for the facility."

Further research by Sanvido (1990b) indicated that four of the Integrated Building Process Model's functions are essential for a project's success. These are the Critical Project Success Factors (CPSF) and "they must be given special and continual
attention to bring about high project performance” (p.7-6). The four factors, which fall into two broad categories, the facility team and the contract, are described below.

The first factor, the facility team, consists of the players involved throughout the project's life cycle. Typically these include the owner, developer, architect/engineer, construction manager, and general contractor. The goal is to build a well organized, cohesive facility team to manage, plan, design, construct, and operate the facility. Secondly, facility experience describes the relative experience of the company and key players. Of particular importance is the experience level of the players in projects similar to the current or proposed one. Thirdly, optimization information is the information used by the players in providing the facility. The goal is to get timely and valuable information from the team players early in the planning and design phases of the facility. Lastly, the contract is the legal document between two parties used to arrange for services to be performed and to establish the business relationship (Sanvido, 1990b). Risk is allocated by clauses contained within the contract. The goal is to provide a series of contracts that allows and encourages the various players to behave as a cohesive team without conflicts of interest and differing goals.

2.3 KEY PROJECT RISK ELEMENTS

The following section highlights research by several authors on the sources of risk and their impact on construction projects. This section concludes by mapping the literature against risk factors considered by experts in selecting the project delivery system.


Neil (1989) studied the management of project risks and uncertainties. This research indicated that risk sources fall into three categories. They are:
a. Technical Uncertainties

b. Contractual Risks

c. Financial Risk

Technical Uncertainties relate to how a building is constructed or the technological project aspects. Building a standard warehouse versus an underground tunnel requires significantly different construction methods and as such presents different project risks.

Contractual risks are found in any contract. The contract language is not always clear and some key issues may be omitted from the agreement. Additionally, one party may perceive they are carrying more than their fair share of the risk, resulting in an adversarial relationship between the contracting parties.

Financial risk is the third risk source. It refers to the monetary (or total project cost) risk assumed by the contracting parties. This risk is generally allocated to the owner on a cost-reimbursable project and to the contractor on a fixed-price contract.

Neil (1989) also attempted to quantify the potential loss with each risk. He identified several methods for handling the seemingly infinite number of combinations of project risk.

a. Traditional - The method applies allowances or contingencies based on past experience. For example, a 10% across the board markup may be applied to the total cost to account for all variables. This is the most popular form of risk management.

b. Simulation - These methods are usually known as Monte Carlo methods. They are simulation techniques used to predict the possible range of project outcomes.

c. Analytical - This method uses probability to assess and combine the effects of individual risk events into an overall measure of risk.
d. Discrete Event - This method employs decision trees and utility theory to assess the project risks.


Ashley (1989) focused on risk allocation as it applied to indemnity, consequential damage, differing conditions, and delay clauses in lump sum contracts. Three conclusions were reached:

a. Careful selection of these clauses is very important. Clauses that do not unfairly allocate risk to the contractor have a positive impact on project performance and the owner-contractor relationship.

b. Every risk has an associated price. These costs appear as visible or hidden costs. Visible costs appear in project bids as a contingency or as insurance costs. Hidden costs increase as a result of burdensome contract conditions. They include the cost of increased claims/disputes, the cost of jeopardizing the project's final quality, and the cost of restricted bid competition.

c. Liquidated damage clauses must be written with caution. They allow the owner retention of contractor payments rather than litigation and they provide the contractor an advance, firm price determination of the risk involved. Studies have also shown, however, that they are viewed by the contractor as a negative incentive and may diminish project performance.


The authors contend there are three phases to risk management: risk identification, risk measurement, and risk management. Each phase is necessary and the process should be continuous. The best method of identifying risks is modifying historical data by insight and experience. Risk measurement techniques are largely mathematical in nature and attempt to quantify the frequency and severity of the risk. Techniques range from the traditional markup to probability techniques such as the
Monte Carlo method. Managing risk involves eliminating, transferring, sharing, reducing, or retaining risk.


Howell contends that selecting the proper team in the construction industry poses special problems because of the short term nature of such organizations. He also noted that the development of a project is actually a reduction of uncertainty as it progresses from conception to reality. Each project has its own associated risks and by definition some pose more risk than others. He developed a two-dimensional Certainty Matrix to illustrate this point. In the matrix, one axis represents the degree of project technical complexity or "how" the project gets built, while the other axis defines the project scope or "what" is to be built.

Conflicts may occur when people have different ideas concerning where the project is located on the matrix. Disputes are also likely to arise when managing a project with inappropriate contractual tools for its location on the matrix. For example, conflict and disputes are likely if the owner uses a contract based on a highly certain view of the project, while the contractor views the project as highly unstable. For example, in the construction of a standard office complex, the owner may select a tight or inflexible contract strategy because he perceives the project as neither very technical nor difficult. After construction begins, however, the prospective tenants may demand significant alterations to their offices. At this point the contractor probably has a different view of the project than the owner did. These scope changes, if not addressed in the contract, can cause problems for the parties involved.


McFarlan believes that managers can avert many financial disasters by first assessing risks prior to starting a project. He identifies three serious deficiencies involving project management. The first two are the failure to assess individual project
risk and the failure to consider the aggregate risk of the portfolio of projects. The third is the lack of recognition that different projects require different managerial approaches. He feels that chief determinants of risk are: project size, project structure or definition of scope, and experience of the team with the technology involved. These are discussed in detail in the following paragraphs.

*Project Size* refers to the magnitude or dimensions of a project. The larger a project is in terms of cost, staffing levels, and number of departments affected by the project, the greater the risk. Multimillion-dollar projects carry more risk than thousand-dollar projects and also affect the firm if the risk is realized. Additionally, another concern is the size of the project relative to a firm's average sized project. The risk is lower for a firm who undertakes a $1 million project whose average job is $2-$3 million than for a firm who undertakes a $250,000 job who has never performed a job costing more than $50,000.

*Project Structure* defines the degree of definition of the desired end product. "In some projects the nature of the task defines the outputs completely. These projects are highly structured. Other projects are more subject to the manager's judgment and are more vulnerable to change. These less structured projects do not have fixed outputs and are subject to change during the life of a project. This type project carries more risk than the highly structured project" (p.143).

*Experience with the Technology* describes the level of expertise of the team members with the technology for the current project. Risk is reduced as the familiarity of the project team with the technology increases. When the team members know "how" to design and implement the given technology, overall project risk decreases. A project that has a slight risk for a technically experienced firm may have a very high risk for a smaller, less technically experienced firm. The latter group can reduce its risk by hiring outside experts and adding them to the team.
McFarlan believes that the mixture of tools, project management methods, and organizational linkages applied to a project should vary according to that project's characteristics: "In short, there is no universally correct way to run all projects" (p. 146). He believes the methods for managing projects fall into four main categories:

a. External integration - These tools include organizational and other communication devices that link the project team's work to the users at both the managerial and lower levels. Examples include: frequency of meetings, and the creation of a user steering committee. This is typically used to reduce risk on poorly structured projects of varied technology and size.

b. Internal integration - These techniques ensure that the team operates as an integrated unit. Examples include: selection of a high percentage of team members with significant previous work relationships, and regular technical status reviews. This is typically used to reduce risk on highly technological projects of varied structure and size.

c. Formal planning - This includes any device that helps to structure the sequence of tasks in advance and estimate the time, money, and technical resources the team will need. Examples include: PERT charts, and feasibility study specifications. This is used to reduce risk on large, low technological projects of varied structure.

d. Formal control - These tools help managers evaluate progress, spot problems, and take corrective action. Examples include: periodic budgeted versus actual status reports, and regular milestone presentation meetings. This is recommended on low technological projects with varied size and structure.

The primary objective of the project manager is to manage the tradeoffs between the project objectives of time, cost, and quality. It is his job to ensure that the expected results are produced in a timely, cost-effective manner. Risk is involved in each because there is a chance the outcome will not turn out as planned. Conventional wisdom had it that the relative importance of the project objectives varied depending on the stage of the project life cycle. During the formation phase, for example, performance or quality was felt to be the most important of the goals. Research has shown, however, that there is no significant difference in the importance project managers place on the three goals in this phase. Performance and schedule, however, were found to be more important than cost in all other phases.

7. The American Society of Civil Engineers (ASCE, 1990)

ASCE defines project risks in terms of the project team. This team consists of the owner, design professional, and constructor. They bring with them different experience levels and skills. As such, risk is associated with the team given these different experience levels. Additionally, no one team member is expected to assume responsibility for results over which he has no knowledge or control.

ASCE also believes "the capabilities, experience, and expertise of the various types of owners significantly influence a project's organizational structure." They refer to two categories of owners, the experienced and the sophisticated.

2.3.1 Summary of Project Risk Factors

In order to better relate the literature to the models developed later in this thesis, Table 2.1 lists the risk factors from the literature and shows how they relate to the risk factors chosen for the final model. In Chapter 3 the experts identify key risk factors used in selecting project delivery systems. These factors are presented on the top two rows of Table 2.1. The two columns on the left of the table refer to the key risks
Table 2.1 Support for Model Risk Factors by Source

<table>
<thead>
<tr>
<th>Author</th>
<th>Risk Factor by Source</th>
<th>Risk Factors Used in Model Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Job Characteristics</td>
<td>Time</td>
</tr>
<tr>
<td>Neil</td>
<td>technical uncertainty</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>contractual risk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>financial risk</td>
<td></td>
</tr>
<tr>
<td>Howell</td>
<td>scope</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>complexity</td>
<td>X</td>
</tr>
<tr>
<td>McFarlan</td>
<td>project size</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>project structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>technical experience</td>
<td></td>
</tr>
<tr>
<td>Meridith and Mantel</td>
<td>cost</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>schedule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>quality</td>
<td></td>
</tr>
<tr>
<td>ASCE</td>
<td>team experience</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: Ashley and Diekmann's material is not applicable here; it is included in the text for completeness.
identified by author. The matrix indicates support from the literature for each risk factor listed. Note that Ashley and Diekmann's material is not listed. It is included in the text, however, for completeness. Additionally, the literature gives no justification to split the "team" into owner and team; the expert responses do, however. It is, therefore, separated here for consistency. Definitions for the Decision Table Risk Factors follow and are also in the Glossary.

- **Cost**: A project risk factor that describes the dollar amount specified for project completion. It is either critical or not critical.

- **Time**: A project risk factor that describes the project duration or schedule. Time is either of the essence or not of the essence.

- **Quality**: A project risk factor, defined as industry standard or above, that refers to the features, described by the plans and specifications, comprising a building.

- **Owner Experience**: A project risk factor that describes the level of expertise of the owner or his hired agent with the requirements of the current project.

- **Team Experience**: A project risk factor that describes the level of expertise of the other team members, less the owner, with the technology for the current project. The team is either experienced or inexperienced.

- **Complexity**: A project risk factor and part of "job characteristics" risk that refers to the degree of difficulty of the project.

- **Scope**: A project risk factor that describes the degree of definition or "what" of a project. The more important of the two elements comprising the "job characteristics" risk factor.

- **Size**: A project risk factor that describes the dimensions or magnitude of a building.
2.4 PROJECT ORGANIZATIONAL STRUCTURES

The second element of the Project Delivery System is the project organizational structure. This section will identify the structures available, present their characteristics, and conclude by illustrating, in a decision table, the risk impact of each organizational structure. For consistency, the format used in the previous section will be duplicated here.

1. The American Society of Civil Engineers (ASCE, 1990)

ASCE lists five different organizational types: the Traditional system, Agency Construction Management, Guaranteed Maximum Price Construction Management (GMP), Design-Build or Turnkey, and Owner Construction. The capabilities, experience, and expertise of the team members significantly influence a project's organizational structure.


This consulting firm lists four different organizational structures: General Contractor/Lump Sum, Construction Management, Design-Build (Single Entity), and Team-Build (Multiple Entity). The strengths and weaknesses of each system are presented to help clients choose the appropriate method for their projects.

3. The Construction Management Association of America (CMAA-1989)

CMAA feels there are virtually an unlimited number of possibilities to successfully deliver projects. In terms of fundamental differences, however, they believe the number of approaches can be reduced to a manageable few. They list five basic organizational structures. They are: Traditional, Design-Build, Construction Management (Agency), Construction Management (GMP), and Negotiated GMP approaches. Additionally, there are several variations to these basic forms and all can effect the degree of risk taking, and the degree of success of the parties involved. For
example, one common variation is based on who actually performs the CM services (e.g., general contractors, architects/engineers, a management firm, or an experienced owner). Other variations include the use of multiple primes, fast tracking, and scope bidding.


Barrie and Paulson identify six different organizational structures. They are the Traditional, Owner-Builder, Design-Build, Design-Manage, Owner-Builder, Construction Management (general contractor), and Construction Management (construction manager) approaches. The authors feel that each has its advantages and disadvantages for particular circumstances. Many of the structures overlap and sometimes it is difficult to define any one particular project's arrangement precisely.


Howell defines three different sets of teams. They are: the Investment Management Team (IMT), the Project Management Team (PMT), and the Work Management Team (WMT). The IMT defines project objectives, assembles funds, establishes project policies, and approves the work of other teams. The PMT is made up of managers from each of the contracting parties with the task of accomplishing the work. They are led by the owner's project manager and are tasked to plan the project. This team also develops the project schedule. The WMT is made up of various contracting parties who actually perform the work. Howell believes that as a project progresses from an idea to completion different teams are more important than others. Additionally, different project types require the services of different teams at different times.

2.4.1 Summary of Project Organizational Structures

The literature describes six basic organizational structures using many different names. In order to better relate the literature to the models developed later in this thesis,
Table 2.2 lists the organizational structures from the literature and shows how they relate to the organizational structures chosen for the final model. Definitions are provided in the Glossary. Each of these basic organizational structures and three others are defined in the next section. The Owner Construction, Negotiated GMP, and Design-Manage structures were eliminated due to a lack of data and/or information on them. The Multiple Primes structure is also discussed but not listed in Table 2.2 because it is actually a variation of the Traditional and Construction Management approaches.

Figure 2.1 illustrates the contract ties of the team members under various organizational structures.

2.4.2 The Traditional System

This approach is characterized by a sequential execution of the delivery phases—planning, design, award/advertise, construction, and occupancy. As the name implies, this is the industry's fundamental approach. It is very popular with both the public and private sectors.

The team members include the owner, architect/engineer and the constructor with one or more subcontractors. The owner relies on the architect/engineer for executing the design and in some cases for providing on-site construction monitoring services. The owner has little or no responsibility for coordination or for work performance. His role is limited to paying the team members, and providing any information and approvals as required by the contract. The architect/engineer is responsible for preparing the plans and specifications in accordance with the owner's desires. They are usually comprehensive and complete before any cost proposals or bids are made. Construction contracts may be negotiated or competitively bid. The constructor does not participate in the design phase and it is his job to build the project in accordance with the plans and specifications. He may subcontract all or a portion of
Table 2.2 Support for Model Organizational Structures by Source

<table>
<thead>
<tr>
<th>Author</th>
<th>Project Organizational Structures by Source</th>
<th>Organizational Structures Used in Model Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Traditional</td>
</tr>
<tr>
<td>ASCB</td>
<td>• Traditional</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM (agency)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM (group)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Design-Build (D/B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Owner Construction</td>
<td>X</td>
</tr>
<tr>
<td>Haines, Lundberg, and Wachler</td>
<td>• General Contractor (lump sum)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• D/B (single entity)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Team Build (multiple entity)</td>
<td></td>
</tr>
<tr>
<td>CMAA</td>
<td>• Traditional</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• D/B</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM (Agency)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• CM (GMP)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• Negotiated GMP</td>
<td>X</td>
</tr>
<tr>
<td>Barrie and Paulson</td>
<td>• Traditional</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• Owner-Builder</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• D/B</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• Design-Manage</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM (general contractor)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• CM (construction manager)</td>
<td>X</td>
</tr>
<tr>
<td>Howell</td>
<td>• Investment Management Team</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• Project Management Team</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>• Work Management Team</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: The Owner Construction and Design-Manage structures were eliminated due to a lack of data and/or information on them.
Figure 2.1 Typical Organizational Structures
the work to speciality contractors. It is also his responsibility to schedule and coordinate all subcontractors, suppliers, and vendors.

Several advantages are realized through the traditional approach. An inexperienced owner needs little involvement in daily project implementation. Construction documents are usually comprehensive and complete before any cost proposals or bids are made. The owner can, therefore, more easily secure any necessary financing.

There are several potential drawbacks under the traditional approach. This approach requires the owner to make a significant investment in the project before a project price is established. He assumes all project risks until the construction contracts are signed. The selected contractor does not have any responsibility to participate in the design process. Therefore, important constructability information may not be used.

Several variations involving team composition and contracting strategies are possible with the traditional approach. There are three options for organizing the construction phase. These include the use of a single general contractor, the use of multiple prime contracts, and the use of multiple prime contracts assigned to a general contractor. When multiple prime contracts are let, the owner is responsible for all scheduling and coordination. This responsibility is often delegated to the owner's agent. The owner usually depends on another party for inspection and acceptance of the constructor's work. Fixed price contracts such as lump sum and unit price are the most common pricing option for the traditional, although a cost-plus with fixed fee contract is also used.

2.4.3 Owner Construction

This method is usually reserved for the large, sophisticated owner. The owner usually does not rely on outside assistance for design or construction services. The
owner's own staff designs the project, provides construction administration services and is solely responsible for the project's quality of construction.

There are four key players with this method—the owner, the owner's staff designer, the owner's staff construction manager, and the prime constructor. Depending on the type of construction there may be more than one prime constructor or the owner may perform the construction with in-house forces. The owner holds all contracts with all parties.

The advantage of this delivery method is that the experienced owner works with his own personnel on all projects, knows his staffs' capabilities, and exercises complete project control.

Potential problems can arise when the owner's staff is not as capable or does not have the capacity for the given project scope and size. Additionally, the owner assumes all project risks and liabilities.

Payment terms to all parties vary from owner to owner.

2.4.4 Turnkey

With the turnkey approach the owner contracts with a single firm or business entity to plan, implement, and control the entire project through completion. The turnkey firm must provide design and construction management services in house or contract with other firms for these services. Two approaches are cited: the Design-Build and the Design-Manage approaches.

1. Design-Build

The players under this approach include the owner, the design-builder, and any subcontractors the design-builder wishes to include. While the primary team members are the owner and the design-builder, the designer is also an important team member. He, however, has no contractual obligation to the owner. All design, vendor, supplier, and construction contracts are held by the design-builder. During the construction
phase, the design-builder may do all the work or elect to subcontract. The owner has little involvement except for making necessary decisions throughout the process. An inexperienced owner may wish to hire outside consultants to ensure the design-build firm is meeting the project goals. This consultant then becomes a key team member.

The design-build approach has several distinct advantages. The owner has a single point of contact, the design-builder with whom to deal. Besides less coordination problems, risk exposure to complex claims is reduced. The owner also has minimal project scheduling and coordination responsibilities. The owner can also begin a project with little information and obtain guarantees from a design-builder that certain project characteristics will be met upon project completion. Construction expertise is also involved in the design phase and through project phasing or fast tracking, overall project completion time is shortened. The design-build approach also allows some construction contracts to be signed before final design is complete.

The design-build approach is not without its share of potential problems. The design function is the obligation of the design-builder and as such the designer may not have any direct relationship with the owner. The owner has few checks and balances and risks losing a certain degree of control over price, schedule, and project performance. He also has little opportunity for involvement and the resolution of problems when they occur. Problem areas usually involve disagreement over the original project scope, quality, time, and the final project cost. With this approach there is also a greater potential for changes and quality disputes.

Team variations with the design-build approach involve a joint venture between a general contractor and a design consultant or a construction firm assuming total project responsibility and subcontracting the design services. Fast tracking or traditional options are also available. Contracts may be fixed or cost plus with the GMP option being the preferred cost plus option.
2. Design-Manage

The players under this approach include the owner, the design-manager, and any number of independent contractors. The design-build and design-manage approaches are similar in that one firm is responsible for both design and construction. The difference, however, is that under the design-manage concept, construction is performed by a number of independent contractors holding contracts with the owner, and managed by a construction manager. Phased construction is also an advantage of this approach. Due to the lack of information on this structure it is omitted from the decision table which follows in a later section.

2.4.5 Construction Management

The construction management concept centers on the construction manager who has the responsibility for managing the entire project from conception to completion. The time of involvement for a CM in a project can vary. There are four common points of entry. They are: prior to selection of the designer; secondly, after selection of the designer and just prior to or after schematic design; thirdly, just prior to or after preliminary design is complete; and lastly, just prior to or after final design and prior to the construction bidding phase. Construction management involves the coordinated efforts of the owner, construction manager, design consultant and constructors. The role of the construction manager is ever increasing. Besides coordinating the efforts of several contractors, services now include project organization and scheduling, the review of design documents, and cost monitoring. There are two recognized forms of Construction Management, Agency and Guaranteed Maximum Price (GMP).

1. Construction Management (Agency)

This form of construction management is also referred to as pure CM, or professional CM. It involves a fiduciary relationship between the owner and the construction manager where the latter works to serve the owner's interests. The
construction manager keeps the owner informed, and makes project recommendations. He does not do any design or construction work and is responsible for project scheduling and coordination.

Team members include the owner, the designer, the construction manager, and the constructors. All contracts to include design and construction services are held by the owner. Trade contracts are either competitively bid or negotiated directly. The construction manager generally has no authority to force contractors to abide by their contractual obligations. The owner maintains the right to enforce the schedule, terminate, and pay contractors on the advice of the construction manager.

Several advantages of construction management (Agency) are common. The close alliance between the CM and the owner increases the likelihood that the owner's interests and project goals will be realized. Project scheduling and coordination are improved over the Traditional approach with the construction manager ensuring the sequencing of all trade contractors. Trade contractors often participate more in the upkeep of the project schedule and are often required to maintain and develop their own schedule in accordance with the CM's master schedule. Besides acting as a "supercoordinator" the CM acts as a troubleshooter providing an early warning for potential problems and as a mediator in claim and dispute resolution. Additionally, the experienced owner has authority to enforce the contract through the advice of the CM. Because of the CM's usual project duties, project documentation for capturing planned versus actual performance is also an advantage. Lastly, the ability to use construction expertise during the planning phase is a significant advantage, particularly, on complex projects.

There is also the potential for problems with this form of project delivery. The owner assumes much of the cost risk. Additionally, since the architect has less of an on-site role than he is accustomed to (i.e., Traditional), quality may suffer if the CM is
inexperienced in quality control. There are also potential liability problems with safety for the same reason. Project success is also largely dependent and capabilities of the CM organization. Under the fast track option there are potential risks involved in beginning work before final cost commitments are known. The CM also has limited contract enforcement powers and an adversarial relationship may develop between the CM and architect since the former is now performing many of the latter's tasks. Lastly, the benefit of having someone responsible for project coordination is diminished if the owner does not delegate or assume the responsibility for scheduling and coordinating the trade contractors.

Variations and options available with this delivery method include: traditional or phased/fast track construction, the use of multiple trade contracts (held by the owner), and the point of entry of the CM on the job. Team members are compensated either under a fixed price or cost reimbursable arrangement.

2. Construction Management (Guaranteed Maximum Price-GMP)

This form of construction management is also known as contractor construction management or CM at risk. The term "GMP" means that at some point during design, the CM modifies the (Agency) agreement with the owner to provide a guaranteed maximum cost for construction.

Team members include the owner, construction manager, architect, and the trade contractors. The main difference between the Agency and GMP options is that in the GMP option the construction manager holds the contracts with the trade contractors. The owner has limited project control and the fiduciary role between he and the construction manager is non-existent. The CM has the right to enforce the schedule, hire and fire the trade contractors, and pay them. He generally has the option of performing portions of the work with his own resources and is responsible for the means, techniques and sequence of construction. The CM is also responsible for
coordinating the trade contractors. The architect’s role is limited to providing the plans and specifications in accordance with the owner’s wishes.

The advantages of the GMP construction management method may include: a guarantee of the construction costs before contract documents are complete, cost savings and sharing incentives if the final construction cost is less than the guaranteed price, less exposure of the owner to safety, scheduling, and coordinating problems between the trades. Lastly, the CM assumes most of the project cost risks.

The disadvantages or potential problems of the GMP construction management option include: owner dissatisfaction when the CM is more concerned with protecting the guaranteed maximum price than getting the project built properly, and the elimination of the implied duties of loyalty and care to the owner. The absence of project controls benefitting the owner is also a possibility since the G.C., acting as the C.M., may not be as interested in controlling the project as he is in building it. Additionally, with the architect/engineer regaining a quality control role an adversarial relationship between the owner and the architect, his agent, and the CM is possible. The potential for bid shopping and slow payment to the trades exists after the GMP is rendered. On public projects, the CM who guarantees the project cost may not be allowed to perform the work if all work is required to be bid. Lastly, design flexibility is greatly reduced once the GMP is established.

Variations and options with this method include: traditional or fast track construction and the use of multiple prime contracts (held by the CM). Payment terms to all other players can be fixed price or cost reimbursable.

2.4.6 Negotiated Guaranteed Maximum Price

This organizational approach is used primarily for private work. It is similar to the GMP option except under this approach the owner and general contractor are committed, from the beginning, to reach an agreement on a guaranteed maximum price
for the cost of construction. The estimate of cost upon which the GMP is based usually requires that design be about 50% complete and the specifications at least 80% complete. To protect his interests the general contractor is normally present during preliminary design. Due to the lack of information, this structure is also not listed in the decision table which follows.

2.4.7 Multiple Primes

Under this system, the owner or the owner's construction manager contracts with several prime contractors to perform phases of the project. This is contrasted to the situation where a single general contractor performs all of the construction work with his own forces or specialty subcontractors. The Multiple Primes system is usually used with either the Traditional or Construction Management approaches.

With the Traditional approach the use of Multiple Primes is usually the result of a statute or law. Under the Construction Management (GMP) approach the construction manager holds the contracts with the prime contractors.

This system also allows construction to begin while the design is finalized (i.e., phased construction). The primary disadvantage of this system is the complexity of scheduling and coordination that is involved. The Multiple Primes system is also called "Separate Bid Packages."

2.5 THE RISK/ORGANIZATIONAL STRUCTURE DECISION TABLE

Table 2.3 is a risk/organizational structure decision table. The top row is based on the type of organizational structure selected in the previous section, while the project risks in the column on the left of the table come from section 2.3.
<table>
<thead>
<tr>
<th>Risk Factors/Org. Structure</th>
<th>Traditional (TD)</th>
<th>Design/Build (D/B)</th>
<th>CM (Agency) (CMA)</th>
<th>CM (General Contractor) (CMGC)</th>
<th>Owner Construction (OC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>no real impact; final project price should be known; may result in a more costly job</td>
<td>better suited for projects with tight budgets</td>
<td>better for higher cost jobs (cm's cost control functions)</td>
<td>cost has no impact</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>best when time is not critical</td>
<td>time is a critical factor</td>
<td>no significant difference (cm's can reduce coordination delays); fast track option can reduce project time</td>
<td>time has no impact</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>good for &quot;industry standard&quot; jobs as well as &quot;monuments&quot;</td>
<td>best suited for industry standard jobs</td>
<td>o.k. for industry standard or above standard projects</td>
<td>no significant difference (industry standard or above standard); quality may suffer if protecting the grp is the primary concern</td>
<td>must be within capabilities</td>
</tr>
<tr>
<td>Owner Experience</td>
<td>better suited for an inexperienced owner</td>
<td>inexperienced owner</td>
<td>better suited for an experienced owner</td>
<td>better for inexperienced (cm assumes many owner responsibilities)</td>
<td>experienced</td>
</tr>
<tr>
<td>Team Experience</td>
<td>good for both; slightly better when team is inexperienced</td>
<td>slightly better for an experienced team (fast track scenario)</td>
<td>ok for both; may be better for an inexperienced team</td>
<td>better for an experienced team</td>
<td>experienced</td>
</tr>
<tr>
<td>Complexity</td>
<td>non-complex jobs</td>
<td>better for industry standard jobs</td>
<td>better suited for more complex jobs requiring the coordination of many trades</td>
<td>better for more complex jobs (opportunity for cost sharing)</td>
<td>must be within capabilities</td>
</tr>
<tr>
<td>Scope</td>
<td>well defined</td>
<td>must be well defined</td>
<td>clear or unclear</td>
<td>slightly better for well defined projects</td>
<td>must be within capabilities</td>
</tr>
<tr>
<td>Size</td>
<td>no impact (this assumes any increase in size is of the same complexity)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Applications</td>
<td>• public and private work</td>
<td>• industrial building</td>
<td>• research &amp; development</td>
<td>• research &amp; development</td>
<td>• large sophisticated owner</td>
</tr>
<tr>
<td></td>
<td>• commercial &amp; residential construction</td>
<td>• rural hospitals</td>
<td>• exploratory &amp; retrofit</td>
<td>• hospitals complex office buildings</td>
<td>• complete project control</td>
</tr>
<tr>
<td></td>
<td>• institutional</td>
<td>• development housing</td>
<td></td>
<td></td>
<td>• assumes all risks &amp; liabilities</td>
</tr>
</tbody>
</table>
The values in each of the cells pertain to the respective risk factor. They were obtained, in general, from the majority opinion of the literature. In cases where the literature was silent, the author applied estimates to determine the rules. The cell values explain, in terms of the risk factor, when each organizational structure applies. The last row, "Typical Applications," lists project types that the literature feels are appropriate for a particular structure.

2.6 PROJECT CONTRACTING STRATEGIES

The third and last element of the Project Delivery System is the contract strategy. This section will define contracting strategy, identify the different contract types, and compare the advantages and disadvantages of each. The end result of this section is a risk/contract strategy decision table.

The contract "is the agreement between two or more people to do something, especially set forth in writing and enforceable by law" (Webster 1988). The literature recognizes six basic contract types. The contracting strategy, then, is the process used in selecting a particular contract type. The literature sources which follows is consistent on the basic contract types. There, however, are minor differences in some of the contract sub-categories.

1. ASCE (1990)

There are three principal contract types: unit-price, lump sum, and cost-plus. Unit-price contracts are common in public-works projects where the quantities or work segments are not precisely known and can only be approximated. Under these contracts a unit price per item is agreed upon and payment is made for the quantities involved. Lump sum contracts involve the constructor calculating the quantities involved and submitting a single lump-sum price for the completed structure. Cost-plus contracts reimburse the constructor for his actual costs plus an agreed upon rate for
overhead and profit. This method differs from the previous two in that in cost-plus contracts the constructor is compensated for his actual costs as opposed to work completed.


Nunnally makes a distinction between method of award contracts and method of pricing contracts. Method of award contracts are either formally advertised or negotiated. Formally advertised contracts involve the owner soliciting bids followed by willing bidders preparing their respective cost estimates. Contract award is given to the lowest, qualified bidder. A negotiated contract is one negotiated between an owner and another party. Contract terms are mutually agreed upon by the parties. The federal government is mandated to use the formally advertised process although negotiated contracts are permitted in certain circumstances. Private owners may choose any method they wish.

Method of pricing contracts are either fixed-price or cost reimbursable. Fixed price contracts specify a final contract or unit price. There is not much flexibility in the final agreed upon price. Cost-plus contracts compensate the worker for his actual costs versus the amount of work completed. Each of these types have several variations.

3. Clough (1964)

Clough groups contracts into two divisions - competitively bid or negotiated. Competitive contracts are prepared on a fixed-price basis and consist of unit-price or lump sum contracts. Negotiated contracts exhibit the common feature that the owner will reimburse the worker for all incurred costs plus an additional fee for overhead and profit.

4. Ashley (1986)

Ashley classifies contracts as either fixed-price or cost reimbursable. Variations and combinations of these basic types can be formed and usually involve trade-offs
between the three objectives of cost, time, and quality. Ashley makes no distinction between fixed-price and lump sum contracts. Fixed-price or lump sum options include either unit price, a series of fixed-price contracts, or fixed-price with escalation contracts. Cost-Reimbursable contracts include cost-plus-percentage fee, cost-plus-fixed fee, direct-cost reimbursable plus fixed-fee for indirects, and the convertible contract. The contractor assumes cost responsibility with fixed-price contracts while the owner has primary cost responsibility with cost-plus contracts.


The authors identify several different contract types. They are: single-fixed price or lump sum, unit price, negotiated cost-plus fixed-fee, or guaranteed maximum-price contracts.

6. The American Institute of Architects (AIA-1978)

AIA categorizes professional services payment as either compensation or reimbursable expense. Compensation is further divided between expense and profit. Expense or cost consists of direct project costs (i.e., personnel expense, reproduction of documents) and indirect project costs (i.e., office overhead, promotional costs). Reimbursable expense is paid separately from compensation. Costs incurred in this area are usually for transportation, living expenses, and postage. The owner and client determine whether an item is assigned as a direct project expense or a reimbursable expense.

2.6.1 Summary of Project Contract Strategies

The literature describes two basic contract categories: Fixed-Price and Cost-Reimbursable. There are many variations of each category. In order to better relate the literature to the models developed later in this thesis, Table 2.4 lists the contract strategies from the literature and shows how they relate to the contract strategies chosen
<table>
<thead>
<tr>
<th>Author</th>
<th>Contract Types by Source</th>
<th>Contract Strategies Used in Model Development</th>
<th>Guaranteed Maximum Price</th>
<th>Cost-Plus Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCB</td>
<td>• unit price&lt;br&gt;• lump sum&lt;br&gt;• cost plus</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nanolly</td>
<td>• unit price&lt;br&gt;• lump sum&lt;br&gt;• fixed with escalation&lt;br&gt;• cost plus percentage of cost&lt;br&gt;• cost plus fixed fee&lt;br&gt;• cost plus fixed fee with gp&lt;br&gt;• cost plus incentive fee</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Clough</td>
<td>• unit price&lt;br&gt;• lump sum&lt;br&gt;• cost plus fee</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ashley</td>
<td>• unit price&lt;br&gt;• series of fixed price&lt;br&gt;• fixed price with escalation&lt;br&gt;• cost plus percentage fee&lt;br&gt;• cost plus fixed fee&lt;br&gt;• direct cost reimbursable plus indirect fee&lt;br&gt;• convertible</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Barrie, Paulson</td>
<td>• unit-price&lt;br&gt;• lump sum&lt;br&gt;• cost plus fixed fee&lt;br&gt;• gp&lt;br&gt;</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>AIA</td>
<td>• compensation&lt;br&gt;• reimbursable</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
for the final model. Definitions are provided in the Glossary. Each of these basic contract strategies and the common variations are defined in the next section.

Figure 2.2 lists the common contract variations from least to most fixed.

2.6.2 Fixed Price Contracts

Fixed-price, or "hard money contracts," include all contracts that establish a fixed sum for the completion of a defined quantity of work. The owner must accept responsibility for providing a complete contract including the project scope, the overall schedule, the desired quality of construction, and the adequacy of site conditions. The owner loses project management control to the contractor under a fixed-price arrangement. Total project time is usually longer because project plans and specifications must be relatively complete before bids are solicited. This type contract is considered to be the best incentive for the contractor to control costs.

On long-term projects, a contractor may have difficulty operating in periods of high inflation. In periods of increased competition, for economic or other reasons, contractors may readily accept fixed price contracts and bid prices will usually be lower than under normal circumstances. Fixed-price contracts allocate significantly more risk to the contractor than cost-reimbursable contracts and they require expenditure of more time and money on design documentation before construction begins. Fixed-price contracts are best used when a fair, reasonable price can be established and detailed scope, design, and specifications are available before work begins. Due to the completeness of the documents, before bidding, scope changes should be minimal. The owner must also ensure he can provide adequate project inspection and supervision. These contracts are usually competitively bid and awarded to the lowest responsible bidder. Typical applications of fixed-price contracts include major public works, commercial and residential construction, heavy engineering construction, and
<table>
<thead>
<tr>
<th>FIXED-PRICE</th>
<th>COST-REIMBURSABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lump Sum</td>
<td>Fixed with</td>
</tr>
<tr>
<td>Unit Price</td>
<td>Escalation</td>
</tr>
<tr>
<td>Guaranteed Maximum Price</td>
<td>Cost Plus Incentive Fee</td>
</tr>
<tr>
<td>Cost Plus Fixed Fee</td>
<td>Cost Plus % of Cost</td>
</tr>
</tbody>
</table>

Note: Contracts are listed, from left to right, from most to least fixed. An owner assumes the smallest cost risk with a Lump Sum contract and the biggest cost risk with a Cost Plus % of Cost contract.

- "hard money" contracts
- more risk to contractor
- more effort, money on design documentation
- bids are let after design is complete
- a more time consuming process
- final project cost is usually not known
- more risk to owner
- usually found on complex or poorly defined projects
- more owner effort needed for contract compliance
- are more flexible

Figure 2.2 Contracts Arranged by Cost Risk to an Owner
smaller industrial and power projects. Several types of fixed-price contracts are described below.

1. **Lump Sum**

   In this type of fixed-price contract the contractor agrees to perform the work for a predetermined price which includes profit. The quantities of material or work items are determined by the contractor. He then submits a single lump sum price for the completed structure. The contractor assumes all of the cost risks. "Front end loading," or overstating project costs during the initial project stages to facilitate positive cash flow for a contractor, is possible with this type contract.

2. **Unit Price**

   Unit-price contracts are similar to lump sum contracts except the prices of specified units of work are fixed and the total project cost varies with the actual quantities of units in place. They are used when the final quantities or work items can only be approximated at the time of bidding. They are common in the engineering construction field and public works projects. The actual quantities installed multiplied by the unit rate determines the price of each line item. The owner assumes the risk of any variations in quantities. Since the final project cost is unknown until contract completion, the total amount paid to the contractor is uncertain. This contract method requires the owner or his representative to maintain a staff to measure the true quantities of work. Drawings and specifications still need to be complete enough for the contractor to assess the project's magnitude and complexity of the work. It is very common for a single project to include a mixture of unit-price and lump sum contracts.

3. **Series of Fixed-Price Contracts**

   This option involves the owner subdividing the work and awarding a series of fixed-price contracts when the design for that portion is complete. This is sometimes called phased construction. This allows a shorter completion time since part of the
project can be built while design continues on the other portions. Additionally, more accurate estimating and bidding is possible given the shorter contract time of each portion. This type contract, however, requires the owner to provide staff or hire outside experts to coordinate and administer the contract. Errors of omission and duplication are also possible. The increased coordination problems among the various contractors increases the likelihood of delays and claims on the owner. It is also more difficult to fix responsibility for problems among the contractors. Lastly, overall project cost may increase given the added overhead of the multiple contracts. This contract type is common when multiple prime contractors are used.

4. Fixed-Price with Escalation

In this fixed-price variation the owner includes a clause accounting for future changes (via an index) in prices of materials or for inflation. This type of contract greatly reduces the contractor's risk on long term projects during unstable economic times. It provides an owner an alternative to the cost-plus contract while giving the contractor an incentive to use his resources efficiently.

2.6.3 Cost-Reimbursable Contracts

Cost-reimbursable contracts include all contracts that provide the contractor reimbursement relative to project costs and that do not require the stipulation of a final fixed price. For several reasons contracts of this sort are usually negotiated. The nature of the construction may make it impractical or impossible to prepare complete plans and specifications prior to the start of construction, time may be a pressing requirement, or major changes may become necessary during the construction phase. In cost reimbursable contracts the owner pays all of the contractor's allowable costs including tools, temporary facilities, home office expenses, and a fee or profit. The emphasis shifts from the amount of work completed to the costs for completing the work. Record keeping becomes more important, necessitating a larger owner staff for
contract administration. It is necessary to track each worker, the hours worked, the
type of work, and the wages paid. Additionally, systems must be developed to record
and file all material invoices, delivery slips, and other records to verify the contractor's
cost.

These type contracts are best used when the scope/cost of the work is not
sufficiently defined to permit the use of a fixed-price contract, qualified contractors are
not willing to accept the risks of a fixed-price contract, the owner wishes to shorten the
design-construction period, and the owner has the ability to closely administer the
contract. Contract award is to the best qualified contractor who submits a competitive
fee and cost proposal. Cost-reimbursable contracts are usually used on industrial
construction projects, high risk heavy construction projects, high technological
projects, research or exploratory work, or projects where the scope is poorly defined
and will change frequently. Several variations of cost reimbursable contracts are
available.

1. Cost-Plus-Percentage-Fee

This type contract reimburses a contractor for his project costs plus a percentage
of the final contract price. It is used almost exclusively by private industry and is
prohibited for most public contracts. The owner assumes the full risk for cost and
schedule and the contractor is, in a sense, rewarded for cost overruns as he is
reimbursed a percentage of the actual project costs. The primary advantages of this
contract is that it permits an earlier start of construction and gives the owner greater
project control.

2. Cost-Plus-Fixed Fee

This type of contract reimburses a contractor for his project costs plus an agreed
set amount. It does not reward a contractor for cost overruns but also does not provide
any incentive for underruns.
3. Cost-Plus-Fixed Fee with Guaranteed Maximum Cost

This is often called a Guaranteed Maximum Price (GMP) contract. In this type contract the constructor guarantees that the total contract price will not exceed a specified amount. It adds some of the risk of a fixed price contract and it is expected that the constructor's fee will include a contingency for this risk assumption. The constructor pays for all project costs in excess of the maximum stipulated value. This contract type provides a ceiling project cost much like the fixed-price contracts. Further incentives can also be provided in the form of sharing clauses for savings or cost underruns.

4. Direct-Cost Reimbursable Plus Fixed-Fee for Indirects

This is a hybrid cost-reimbursable-fixed-price contract in which owner risk is reduced by approximately the amount of the indirects, tools, and supplies necessary for the contractor to complete the work. The contractor has some incentive to reduce costs since overhead and other indirect costs are his responsibility.

5. Convertible Contract

This type contract starts as cost-reimbursable and is converted to fixed-price as the project's scope becomes fully established. In that respect it becomes a guaranteed maximum price contract as soon as the price becomes fixed.

6. Cost-Plus Incentive Fee

This type contract is designed to provide an incentive for reducing project cost. A constructor's target fee is increased or decreased according to the final project cost. He receives an increased fee if he is able to exceed the project goals (i.e., time, cost, quality).

2.6.4 Discussion of Contracts

Fixed-price contracts have several advantages. The owner benefits from price competition given a pool of competent contractors bidding on the project. Additionally,
these type contracts have well established legal and contractual precedents. In general, the overall project cost is determined before the contract is awarded. The exception is with unit price and escalation contracts when variations in quantity and price exist. The inexperienced owner can also benefit since he has a minimal role in the construction process. Lastly, this type contract provides the best opportunity for the contractor to reduce costs and meet schedule while affording him the opportunity to increase profits through improved productivity.

There are also several disadvantages with Fixed-Price contracts. Design and construction time is longer given the need for complete plans and specifications. The contractor also bears economic risk for many factors not under his control and an owner may place an additional burden on the contractor for risks he does not wish to assume. Any changes and unforeseen difficulties frequently result in disputes and extra costs to the owner and contractor. The contractor has a minimal input in the design process. Any contractor financial problems can cause serious problems. The contractor also has no incentive to exceed the quality standards beyond the required specifications. Lastly, for many of the reasons just mentioned fixed-price contracts increase the likelihood of an adversarial relationship between an owner/agent and the constructor.

Cost-Reimbursable contracts have several advantages and disadvantages. The advantages include a faster design-construction process since construction can start before plans are complete. This results in a reduced overall project completion time. Additionally, there is flexibility in regard to project changes in terms of project scope and design. They also provide an option when constructors are unwilling to accept high risks. Less owner involvement is required to enforce quality provisions. They also provide a better working relationship between owners and constructors.
The disadvantages include a more costly contract, more risk, more owner and staff involvement to enforce cost and schedule provisions, and a more detailed negotiation and selection process. The owner also assumes most of the cost risks. The final project cost is also not known.

2.7 THE RISK/CONTRACT STRATEGY DECISION TABLE

Table 2.5 is a risk/contract strategy decision table. The top row is based on the type of contract strategy selected in the previous section, while the project risks in the column on the left of the table come from section 2.3.

The values in each of the cells pertain to the respective risk factor. They were obtained, in general, from the majority opinion of the literature. In cases where the literature was silent, the author applied estimates to determine the rules. The cell values explain, in terms of the risk factor, when each organizational structure applies. The last row, "Typical Applications," lists project types that the literature feels are appropriate for a particular structure.

2.8 CONCLUSION

This chapter presented a review of the literature on Project Delivery Systems. It was shown where the selection of a project delivery system fits into a project's life cycle and explained that it is a Critical Project Success Factor. Additionally, each of the project delivery systems elements were identified with a discussion of their respective characteristics, advantages, and disadvantages. Decision tables with rules linking the different organizational structures and contract types for different project conditions were developed. Chapter 3 discusses the model development process.
### Table 2.5 Risk/Contracting Strategy Decision Table for the Literature

<table>
<thead>
<tr>
<th>Risk Factors/Contract</th>
<th>Fixed - Unit Price (UP)</th>
<th>Fixed - Lump Sum (LS)</th>
<th>C.R - Cost Plus Fee (CPF)</th>
<th>C.R - GMP (GMP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>cost is critical or not critical; final project cost is not known; contractor determines unit price</td>
<td>final cost is known; loan, capital investment considerations</td>
<td>final cost not known; no incentive for a contractor to reduce costs; no incentive for underruns</td>
<td>maximum cost is known; potential for incentives sharing</td>
</tr>
<tr>
<td>Time</td>
<td>critical or not critical</td>
<td>time is not critical</td>
<td>time is critical</td>
<td>critical or not critical</td>
</tr>
<tr>
<td>Quality</td>
<td>the specified quality level can be industry standard or above industry standard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner Experience</td>
<td>o.k. for an experienced and inexperienced owner</td>
<td>slightly better for an inexperienced owner</td>
<td>requirement for an experienced owner; staff is greatly increased for project monitoring</td>
<td></td>
</tr>
<tr>
<td>Team Experience</td>
<td>o.k. for an experienced and inexperienced team</td>
<td>slightly better for an inexperienced team</td>
<td>a more experienced team is essential to ensure an owner doesn’t needlessly pay for an inexperienced team's mistakes</td>
<td></td>
</tr>
<tr>
<td>Complexity</td>
<td>generally more complex projects</td>
<td>industry standard</td>
<td>better suited for complex jobs</td>
<td></td>
</tr>
<tr>
<td>Scope</td>
<td>final quantities not known; scope is well defined</td>
<td>clear scope, well defined</td>
<td>better suited for projects that are poorly defined</td>
<td>clear</td>
</tr>
<tr>
<td>Size</td>
<td>size is directly proportional to cost</td>
<td>suited for all sized projects</td>
<td>suited for all sized projects</td>
<td></td>
</tr>
</tbody>
</table>
| Typical Applications   | * engineering construction  
* tunnels | * parking garages  
* classroom/office buildings | * private industry  
* industrial  
* research and development  
"one of a kind" | * private industry  
* industrial  
* research and development  
* custom housing |

Note: The Cost-Reimbursable Plus Fee column applies to several Cost-Reimbursable Contracts. These include: Cost Plus % of Cost, Cost Plus Fixed Fee, and Cost Plus Incentive Fee. There was no significant difference between the three.
CHAPTER 3
MODEL DEVELOPMENT

In order to develop a method to select project delivery systems, rules were developed from the literature (Chapter 2). This chapter develops a similar decision table using the data provided by seven experts who select project delivery systems. This provides a realistic check on the tables that were developed from data provided by researchers for differing purposes.

This chapter outlines the data collection process. The first step in the process was to design a questionnaire which would help identify the critical project risk factors and their impact on the selection of an organizational structure and contract strategy. Next, the experts were selected. Thirdly, the data had to be collected from these experts, and finally, the data was analyzed and reduced to decision tables, similar to those illustrated in the previous chapter.

3.1 QUESTIONNAIRE DEVELOPMENT

The purpose of the questionnaire was to illicit responses from experts on project delivery that would serve as input to the PDSS model. The questionnaire (Appendix A) was divided into five parts: general information, project risks, organizational structures, contract strategies, and case studies. Specifically, the questions were based on the literature search and the resulting decision tables in Chapter 2 and designed to clarify the rules. The questions are non-leading, and structured so as to obtain unbiased responses. Redundancy was purposely built in to check consistency of results.

The general information section asked for background information about the experts in terms of their experience in project delivery and the general project
characteristics in which they had experience. The second section, risk, focused on the 
experts measure risk, the critical project risk factors, and the risk impacts on various 
project characteristics. Thirdly, questions on project organizational structures identified 
each company's most used organizational structure, and the structure selected given the 
absence or presence of the previously identified risk factors. The fourth section, 
contracts, identified the most used contract type and the contract selected given the 
presence or absence of the project risk factors. Throughout the interview process, it 
was necessary to continually remind the experts of terms related to risk, organizational 
structures, and contract strategies. It wasn't that they were unfamiliar with these terms, 
rather, each expert seemed to have his own definitions of these terms. For consistency 
of results it was essential that everyone respond according to a standard set of 
definitions presented in the Glossary.

The last section asked the experts to identify both their best and worst project in 
terms of the selected project delivery approach. The intent was to have a data base of 
jobs that failed or succeeded as a result of the selected delivery approach. More often 
than not, however, the experts really didn't know why their projects succeeded or 
failed. Only in three or four instances was the selected delivery approach, or some 
other factor cited for a project's success or failure. Most cited symptoms of success or 
failure, such as "we succeeded because the owner was happy or we came in under 
budget." Likewise, reasons for job failure included symptoms such as "the team 
couldn't work together, or we finished six months behind schedule."
3.2 EXPERT SELECTION

Experts were chosen from members of the Consortium for the Advancement of the Building Sciences (CABS) and several independent consultants. CABS is a partnership between Penn State University and firms focusing on advancing the state of the art in the building industry. CABS members provide annual grants to the university to support CABS activities and also participate in projects undertaken by CABS. Members serve on technical committees, define industry problems, and formulate approaches to these issues. CABS is comprised of twenty firms including owners, architects/engineers, constructors, and consultants. A research brief, outlining the PDSS study, was sent to all twenty members. A total of six CABS members and one related consultant participated in this study. Five of the experts are principals in their companies while the other two are their firms senior project managers. The average experience of the participants in project delivery is 25 years. For the purposes of this study an expert is defined as someone with over 10 years of successful project delivery experience.

3.3 INTERVIEW PROCEDURE

The interview process took on average about 4 hours per respondent. This included answering the initial questionnaire (2 hours) and follow-up interviews (2 hours) to clarify responses. Responses were given to questions in five different categories: general information, risk, organizational structures, contract strategies, and case studies.

3.3.1 General Information

The first section, general information, asked the experts to describe the typical project with which they had PDSS experience. The following is a project profile with data in terms of the largest, average, and smallest values in each category.
• project cost (range): (260; 13; 10) million
• project size (range): (1,400,000; 150,000; 50,000) ft²
• project duration (range): (60; 18; 10) months
• project location: mostly urban

The last question in this section asked the experts to identify the factor which was most important on the projects they worked. Most of the experts felt cost was the main project concern.

3.3.2 Risk

The second category, risk, attempted to develop a listing of the critical project risk factors, rank them in order of importance, and determine their effect on the selection of a project organizational structure and contract strategy. All the respondents measure project risk qualitatively versus quantitatively. Only two respondents even remotely attempted to perform some type of mathematical analysis to quantify the specific project risks. The experts also felt that the particular job characteristics (i.e. project scope and complexity) pose the most risk. Table 3.1 illustrates the other critical project risk factors.

Although most felt that project scope and complexity should be grouped together, most believed that scope was the most important of the two. Together, these two characteristics label a project as being "easy" or "hard." Additionally, the experts felt that the "team" should be differentiated between the owner and other team members. In terms of importance, owner experience was given a slight edge over team experience. The feeling was that the owner had more of an impact on the project's outcome.
Table 3.1 Determining the Critical Project Risk Factors

<table>
<thead>
<tr>
<th>Question 2.3.1: Which project risk factors are the most critical?</th>
<th>Number of Positive Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Project Characteristics (scope and complexity)</td>
<td>• 6/7</td>
</tr>
<tr>
<td>• Time Available</td>
<td>• 5/7</td>
</tr>
<tr>
<td>• Owner Experience</td>
<td>• 4/7</td>
</tr>
<tr>
<td>• Team Experience</td>
<td>• 4/7</td>
</tr>
<tr>
<td>• Cost</td>
<td>• 3/7</td>
</tr>
</tbody>
</table>

Project characteristics (scope and complexity) were viewed as affecting all the other risk factors. That is, if risk from the project characteristics is high, the other risk factors will also pose a high risk and vice versa. Time, or the lack of it, also poses a significant risk and very often magnifies the other risk factors. Even a relatively simple job can experience problems if time becomes "of the essence." It was also felt that an experienced owner and team could overcome most job problems and mitigate the risks posed by the project characteristics. Lastly, the experts believed cost was always a concern but lost importance as the project progressed. It was also that the presence or absence of the other risk factors directly impacts project cost. For example, if a project is poorly defined or the team is inexperienced costs will most likely increase. The identified critical project risk factors are key elements in the development of the respective risk factor/organizational structure and risk factor/contract strategy decision tables.
3.3.3 Organizational Structure

This section attempts to determine how project risks affect the selection of a particular organizational structure. Initially, total project risk was considered as a whole, then it was separated in later questions. Additionally, the preferred organizational structure, given different risk levels and risk factors is identified. The results are tabulated in the form of a risk factor/organizational structure decision table and are found in section 3.4.

The Traditional organizational structure was the most preferred project organizational structure. Five out of seven respondents preferred this type structure over all others. One expert preferred a Construction Management approach (G.C.) while one had no set preference.

Table 3.2 illustrates a good correlation between the previously identified critical project risk factors and the impact of these factors on the selection of a project organizational structure.

<table>
<thead>
<tr>
<th>Question 3.4: What do you consider to be the one or two most critical risk factors in selecting an organizational structure?</th>
<th>Number of positive responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Job Characteristics</td>
<td>• 6/7</td>
</tr>
<tr>
<td>• Time</td>
<td>• 3/7</td>
</tr>
<tr>
<td>• Owner Experience</td>
<td>• 3/7</td>
</tr>
<tr>
<td>• Cost</td>
<td>• 3/7</td>
</tr>
<tr>
<td>• Team Experience</td>
<td>• 2/7</td>
</tr>
</tbody>
</table>
The differences between this table and Table 3.1 are slight. In Table 3.2 cost was valued equally with owner experience and valued higher than team experience. Additionally, the respondents had a definite preference for a particular organizational structure given a project's composite risk. Table 3.3 shows that the Traditional approach is the preferred structure when overall risk is low while Construction Management is the preferred structure when overall risk is high.

**Table 3.3 Overall Risk versus Organizational Type**

<table>
<thead>
<tr>
<th>Questions 3.5, 3.6 What organizational structure do you use if the overall project risk is &quot;high&quot;? is &quot;low&quot;?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>if risk is low</strong></td>
</tr>
<tr>
<td>Traditional</td>
</tr>
<tr>
<td>4/7</td>
</tr>
<tr>
<td>Design-Build</td>
</tr>
<tr>
<td>3/7</td>
</tr>
<tr>
<td>Construction Management</td>
</tr>
<tr>
<td>2/7</td>
</tr>
</tbody>
</table>

Note: Multiple answers account for responses adding to more than 7

It is understood that many risk factors are present on a job, often at the same time. Nevertheless, in order to build the model, it is necessary to isolate each individual risk factor and determine what would be the preferred organizational structure if only the selected risk factor was present. Table 3.4 illustrates the results.

The experts favor the traditional approach when job complexity is "easy," when project scope is well defined and when the team is inexperienced or experienced. Construction Management is the preferred choice when job complexity is "hard," and project scope is poorly defined. The design/build approach fell somewhere between the traditional and construction management approaches in terms of project risk. Most felt that this approach was best suited for low-medium risk projects. Project size had no
impact on the selection of an organizational structure. It was felt that a bigger or smaller job matters little in the selection of a project team.

Table 3.4 Individual Risk Factors versus Organizational Type

<table>
<thead>
<tr>
<th>Question 3.7 What organizational structure do you select when:</th>
<th>CM 3/7</th>
<th>D/B 2/7</th>
<th>Traditional 1/7</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Time is of the essence?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cost is the main concern?</td>
<td>Traditional 4/7</td>
<td>D/B 2/7</td>
<td>CM 2/7</td>
</tr>
<tr>
<td>• Quality is the main concern?</td>
<td>Traditional 2/7</td>
<td>D/B 2/7</td>
<td>CM 1/7</td>
</tr>
</tbody>
</table>

In certain cases it was difficult to establish a preference for one organizational structure or another. This occurred when the same number of positive responses are given for two or more organizational structures and in cases where the "no preference" responses outnumber the positive responses. For example, four experts felt both the Traditional and Design/Build were the best structures given an inexperienced owner. Likewise, only two felt the CM (Agency) approach was appropriate when cost was not critical. Judgments in interpreting the rules are, therefore, necessary in these cases.

In concluding this section some additional observations need to be made. There is a definite tendency to go with the "usually used" structure. Additionally, there is a definite tendency to select the traditional approach when project risk is perceived as "normal" and the construction management approach when project risk is perceived as "abnormal." The experts understood the two different types of construction management but consistently referred to them interchangeably. Lastly, project scope and complexity were viewed together and seen as presenting the most risk. The experts looked at these two characteristics first to determine "normal" versus "abnormal."
3.3.4 Contracts

This section attempts to determine how project risks affect the selection of a particular contract strategy. Additionally, the preferred strategy, given different risk levels and risk factors is identified. The results are tabulated in the form of a risk factor/contract strategy decision table and are found in section 3.4.

Although there are different types of fixed and cost-reimbursable contracts, the respondents didn't distinguish between the two. In fact, many of the experts consistently combined the organizational structure and contract type referring to Traditional-Lump Sum and CM-GMP contracts. In general, this is correct but there are other variations associated with each different organizational structure. Fixed price contracts (4/7) was the most preferred contract type followed by cost reimbursable contracts (2/7). One respondent had no preference.

Project characteristics, completeness and accuracy of the contract documents, and time, were the most critical risk factors cited. Table 3.5 illustrates this point.

Table 3.5 Risk and the Selection of a Contract Strategy

<table>
<thead>
<tr>
<th>Question 4.6: What do you consider to be the one or two most critical risk factors in selecting a contract strategy</th>
<th>Number of positive responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Job Characteristics</td>
<td>• 4/7</td>
</tr>
<tr>
<td>• Accuracy of the Contract Documents</td>
<td>• 4/7</td>
</tr>
<tr>
<td>• Owner experience</td>
<td>• 3/7</td>
</tr>
<tr>
<td>• Time</td>
<td>• 3/7</td>
</tr>
<tr>
<td>• Team Experience</td>
<td>• 2/7</td>
</tr>
</tbody>
</table>
This table is very similar to Table 3.2. Cost was not considered a critical risk factor in selecting a contract strategy. Again, it was felt that cost is really part of the other risk factors. Project characteristics and the condition of the contract documents received the most responses. Although they are similar, the respondents felt that it was critical for the design team to communicate the owners intent, and describe the project characteristics via the plans and specifications. Quality requirements, and project size also had little impact on the selection of a contract type.

The respondents had a definite preference for a particular contract strategy given a project's composite risk. Table 3.6 shows that Fixed-Price contracts are preferred when overall risk is low, while Cost-Reimbursable contracts are preferred when overall risk is high.

The respondents had a definite preference for a particular contract strategy given overall project risk. The same respondents who preferred a Fixed-Price contract (low risk) preferred a Cost-Reimbursable contract (high risk) and vice versa. Likewise, the two "no preference" responses in each category came from the same two respondents.

Table 3.6 Overall Risk versus Contract Strategy

<table>
<thead>
<tr>
<th>Questions 4.4, 4.5 What contract strategy do you use if the overall project risk is &quot;high&quot;? is &quot;low&quot;?</th>
</tr>
</thead>
<tbody>
<tr>
<td>if risk is low?</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>• Fixed-Price</td>
</tr>
<tr>
<td>• Cost-Reimbursable</td>
</tr>
<tr>
<td>• No Preference</td>
</tr>
</tbody>
</table>

Additionally, in terms of project risks, the following findings were noted. As time becomes more critical cost-reimbursable contracts are preferred. Cost-
Reimbursable contracts are also preferred when the quality level specified is above industry standard, job complexity increases, and when project scope is poorly defined. Fixed-Price contracts are preferred when time is not critical, when the quality level specified is industry standard, when project complexity decreases, project scope is clear, and when the team is inexperienced. There was no preference for either contract strategy in terms of cost and project size.

It was also necessary, in certain cases, to estimate the preferred contract strategy. This was not as big a problem as in determining the preferred organizational structure. This is due to the fact that the experts chose to only differentiate contracts as either Fixed or Cost-Reimbursable. For example, three experts felt a Fixed-Price contract was more applicable when the team was inexperienced, and three felt this contract type applied when the team was experienced. The bigger problem, however, occurred later in the model development process when it became necessary to determine what contract type applied within each category.

Lastly, there is also a tendency for the experts to use the contract strategy they are most comfortable with, irrespective of the project risk factors. The owner's experience level and the degree of project control desired are also key factors in the selection of a contract type. If the project characteristics risk is perceived as low, fixed-price contracts are preferred. On the other hand, when the job characteristics risk is perceived as high, cost-reimbursable contracts are preferred.

3.3.5 Case Studies

The last section of the questionnaire asks the experts to describe their best and worst project experiences. It was left up to the experts to define what "best" and "worst" meant. Most referred to the generally accepted goals of cost, time, and quality in describing their projects. In addition to these characteristics team cohesiveness, or the lack of it, and the degree of project communication were also cited.
The purpose of this section, as described earlier, was to obtain data on projects that succeeded or failed because of the selected delivery approach. In only a few instances was this the case. It was necessary, after model development and prior to testing, to obtain additional project information to explain the cause of the project's success or failure. Appendix B presents the project information.

3.4 EXPERT DECISION TABLES

Tables 3.7 and 3.8 show the expert rules for the Organizational Structure and Contract Strategy. These tables consolidate the responses presented in section 3.3.3 and 3.3.4. The column on the left side of the table lists the risk factors and the top row lists the organizational structure or contract strategy. Each cell describes the risk factor condition of the respective organizational structure or contract strategy. The value in parentheses in each cell represents the number of experts who gave this response. The last row, "Typical Applications," gives project types the experts believe apply to a particular organizational structure or contract strategy. As mentioned earlier in this chapter, project scope and complexity are combined to form the risk factor project characteristics.

3.5 CONCLUSION

This chapter outlines the data collection process. Data was obtained by interviewing experts in the project delivery field, analyzing their responses, and developing expert models in the form of decision tables. These models identify critical project risks, and organizational structures and contract strategies the experts feel are most appropriate for different risk situations. The rules obtained from the models serve as input to the Project Delivery Selection System (PDSS). The PDSS is identified in the next chapter.
Table 3.7 Risk/Organizational Structure Decision Table for the Experts

<table>
<thead>
<tr>
<th>Risk Factors/Org. Structure</th>
<th>Traditional (TD)</th>
<th>Design/Build (D/B)</th>
<th>CM (Agency) (CMA)</th>
<th>CM (General Contractor) (CMGC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Characteristics</td>
<td>easy,&quot;cookie cutter&quot; (4/7)</td>
<td>better suited for more simplistic/straightforward projects (3/7)</td>
<td>very complex and poorly defined projects (2/7)</td>
<td>complex, but fairly well defined projects (2/7)</td>
</tr>
<tr>
<td>(scope, complexity)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>not critical (6/7)</td>
<td>time is a critical factor (5/7)</td>
<td>time is generally critical (4/7)</td>
<td>time is generally critical (4/7)</td>
</tr>
<tr>
<td>Owner Experience</td>
<td>better suited for an inexperienced owner (relies on a/e) (4/7)</td>
<td>inexperienced owner (4/7)</td>
<td>better suited for an inexperienced owner (2/7)</td>
<td>critical that the owner be experienced (3/7)</td>
</tr>
<tr>
<td>Team Experience</td>
<td>better for an inexperienced team (4/7)</td>
<td>slightly better for an experienced team (complete faith in team) (4/7)</td>
<td>ok for both; may be better for an inexperienced team (a/e can troubleshoot) (2/7)</td>
<td>critical that an experienced team be in place (3/7)</td>
</tr>
<tr>
<td>Quality</td>
<td>best for industry standard projects (5/7)</td>
<td>best suited for industry standard jobs (inflexible) (3/7)</td>
<td>&quot;monument&quot; type projects (a/e has no financial responsibility) (3/7)</td>
<td>suited for all quality ranges but lesser quality level than &quot;agency&quot; (3/7)</td>
</tr>
<tr>
<td>Cost</td>
<td>is a critical factor (4/7)</td>
<td>no preference (4/7)</td>
<td>is not critical (2/7)</td>
<td>is important but not critical (2/7)</td>
</tr>
<tr>
<td>Composite Risk</td>
<td>low risk (4/7)</td>
<td>low-medium risk (5/7)</td>
<td>higher risk projects (4/7)</td>
<td></td>
</tr>
<tr>
<td>Typical Applications</td>
<td>office buildings (4/7)</td>
<td>light manufacturing jobs (5/7)</td>
<td>hospitals (2/7)</td>
<td>major high rise office buildings (2/7)</td>
</tr>
<tr>
<td></td>
<td>parking garages</td>
<td>rural hospitals</td>
<td>laboratories</td>
<td></td>
</tr>
</tbody>
</table>

Note: () indicates the number of positive responses, "no preference" responses are included in totals; answers reflect majority responses.
Table 3.8 Risk/Contract Strategy Decision Table for the Experts

<table>
<thead>
<tr>
<th>Risk Factors/Contract Strategy</th>
<th>Fixed-Price</th>
<th>Cost-Reimbursable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(scope, complexity)</td>
<td>well defined scope; complex projects apply as long as scope remains well defined (6/7)</td>
<td>poorly defined, complex jobs (6/7)</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>not critical (6/7)</td>
<td>time is a critical factor (5/7)</td>
</tr>
<tr>
<td><strong>Owner Experience</strong></td>
<td>better suited for an inexperienced owner (5/7)</td>
<td>experienced owner; needs to look out for own interests (5/7)</td>
</tr>
<tr>
<td><strong>Team Experience</strong></td>
<td>o.k. for both; may be slightly better for an inexperienced team; owner has less project control, involvement (4/7)</td>
<td>critical that an experienced team be in place (cost, time issues) (6/7)</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>industry standard; owner doesn't know if he is getting the &quot;A&quot; team (4/7)</td>
<td>all quality ranges; the owner gets what he pays for (6/7)</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>no preference; use when final price must be known (4/7)</td>
<td>no preference; more appropriate when cost is not critical</td>
</tr>
<tr>
<td><strong>Composite Risk</strong></td>
<td>low- medium risk (6/7)</td>
<td>high risk (6/7)</td>
</tr>
<tr>
<td><strong>Typical Successful</strong></td>
<td>- office buildings</td>
<td>- retrofit jobs</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>- residential construction</td>
<td>- hospitals</td>
</tr>
</tbody>
</table>

Note: () indicates the number of positive responses, "no preference" responses are included in totals; answers reflect majority responses
CHAPTER 4

THE PROJECT DELIVERY SELECTION SYSTEM (PDSS)

This chapter presents the Project Delivery Selection System (PDSS). The PDSS is defined and the model development process, from decision tables to decision trees is explained. The chapter concludes by illustrating the model's use on a sample project.

4.1 THE PDSS FUNCTIONS

The Project Delivery Selection System is a method that an owner could use to select a project organization structure and contracting method for a given project. It uses decision trees as the model for making the proper project delivery decisions. The PDSS consists of the following three separate and distinct activities: (see Figure 4.1).

1. Collect data to determine the project risks.
2. Select the project organizational team.
3. Select the project contract strategy.

Determining the risks of the current project is a necessary and vital first activity. Each of the critical project risk factors, in order of importance, are: project characteristics, time, owner experience, team experience, quality requirements, and cost. The success of the remaining two activities is dependent on the completeness and accuracy of this process.

Selecting the project organizational structure is the second activity. There is a tendency in the industry to combine steps 2 and 3, but this system explicitly separates
Figure 4.1 The Activities Comprising the Project Delivery Selection System (PDSS)
the two decisions. Although some organizational structures and contract strategies are commonly used together, it was shown that there are many variations and numerous organizational structure/contract strategy combinations. The reasoning behind selecting the structure second is that it was viewed by the experts as being more important than the selection of a contract strategy. This activity is completed by entering the appropriate organizational structure decision tree, presented later in this chapter, and applying the pre-determined risk factor ratings.

The final activity is the selection of the project contract strategy. The same risk factors and their ratings used in the previous step are used here. If the risk factors change prior to the selection of the contract strategy use the risk factor values applicable at that time. To complete this activity, the pre-determined risk factors are applied to the contract decision tree, presented later in this chapter.

4.2 PDSS MODEL DEVELOPMENT

The model development process consists of two steps: the construction of decision tables similar to those illustrated in the previous two chapters and the development of the decision trees (the model).

The decision tables are illustrated in Tables 4.1 and 4.2. The critical project risk factors, in the left column of each table, are in order from most to least critical. Values of each variable are provided in cells for each of four different organizational structures and four contract strategies respectively. In reading the tables, first select a risk factor then locate the value or description for the risk factor in the table. Then read up to the respective organizational structure or contract strategy cells to determine which is most applicable.

The PDSS decision tables were developed by combining tables developed from both the literature and the experts. In many cases the literature and experts agree, while
Table 4.1 A PDSS Risk/Organizational Structure Decision Table

<table>
<thead>
<tr>
<th>Risk Factors/Org. Structure</th>
<th>Traditional (TD)</th>
<th>Design/Build (DB)</th>
<th>CM (General Contractor) (CMOC)</th>
<th>CM (Agency) (CMA)</th>
<th>Risk Factor Range</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Characteristics (scope, complexity)</td>
<td>well defined, better suited for industry standard jobs</td>
<td>well defined projects; industry standard as well as slightly complex jobs</td>
<td>fairly well defined, relatively complex</td>
<td>poorly defined, highly complex jobs</td>
<td>well defined</td>
<td>TD</td>
</tr>
<tr>
<td></td>
<td>not of the essence</td>
<td>better when time is of the essence</td>
<td>time is generally critical</td>
<td>o.k. for both - slightly better when time is of the essence</td>
<td>poorly defined</td>
<td>DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMOC</td>
</tr>
<tr>
<td>Owner Experience</td>
<td>o.k. for both - better suited for an inexperienced owner</td>
<td>inexperienced owner; owner loses &quot;checks and balances&quot;</td>
<td>critical that the owner be experienced</td>
<td>o.k. for both - better for an inexperienced owner</td>
<td>experienced</td>
<td>CMOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMA</td>
</tr>
<tr>
<td>Team Experience</td>
<td>o.k. for both - better for inexperienced</td>
<td>better for an experienced team</td>
<td>critical that an experienced team be in place</td>
<td>o.k. for both - slightly better for an inexperienced team</td>
<td>experienced</td>
<td>CMA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TD, DB</td>
</tr>
<tr>
<td>Quality</td>
<td>industry standard as well as &quot;innovative&quot;</td>
<td>industry standard and jobs with a little higher quality requirement</td>
<td>o.k. for both - better for industry standard jobs</td>
<td>o.k. for both - better for higher quality projects</td>
<td>above standard</td>
<td>CMOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TD</td>
</tr>
<tr>
<td>Cost</td>
<td>better when cost is important but not &quot;critical&quot;</td>
<td>o.k. for both - better when cost is critical</td>
<td>better when cost is critical</td>
<td>not critical</td>
<td>critical</td>
<td>DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>not critical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMA</td>
</tr>
<tr>
<td>Company Risk</td>
<td>low risk</td>
<td>low - medium risk</td>
<td>high risk</td>
<td>high risk</td>
<td>low</td>
<td>TD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CMA</td>
</tr>
<tr>
<td>Successful Applications</td>
<td>Research/Classroom Building</td>
<td>Manufacturing Plant</td>
<td>Hospital</td>
<td>Hospital</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Table 4.2 A PDSS Risk/Contract Strategy Decision Table

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Characteristics (scope, complexity)</td>
<td>well defined; complexity not an issue as long as scope remains defined</td>
<td>well defined scope but final quantities not known; complex or non-complex jobs</td>
<td>scope fairly well defined; higher complex projects</td>
<td>poorly defined, complex projects</td>
<td>well defined</td>
<td>LS</td>
</tr>
<tr>
<td>Time</td>
<td>not of the essence</td>
<td>not of the essence</td>
<td>o.k. for both; better when time is of the essence</td>
<td>of the essence</td>
<td>of the essence</td>
<td>CPF</td>
</tr>
<tr>
<td>Owner Experience</td>
<td>better for an inexperienced owner</td>
<td>better for an inexperienced owner</td>
<td>o.k. for both; better for an experienced owner</td>
<td>experienced</td>
<td>experienced</td>
<td>CPF</td>
</tr>
<tr>
<td>Team Experience</td>
<td>o.k. for both; better for an inexperienced team</td>
<td>o.k. for both; slightly better for an experienced team</td>
<td>experienced</td>
<td>experienced</td>
<td>experienced</td>
<td>CPF</td>
</tr>
<tr>
<td>Quality</td>
<td>industry standard and &quot;monuments&quot;</td>
<td>industry standard</td>
<td>o.k. for both; slightly better for industry standard jobs</td>
<td>higher than industry standard</td>
<td>above standard</td>
<td>CPF</td>
</tr>
<tr>
<td>Cost</td>
<td>better when cost is important but not critical</td>
<td>generally critical with some flexibility to account for unknown quantities</td>
<td>o.k. for both; slightly better when cost is not critical</td>
<td>not critical</td>
<td>critical</td>
<td>LS</td>
</tr>
<tr>
<td>Composite Risk</td>
<td>low</td>
<td>low-medium</td>
<td>medium-high</td>
<td>high</td>
<td>low</td>
<td>LS</td>
</tr>
<tr>
<td>Typical Successful Applications</td>
<td>Research/Laboratory</td>
<td>This contract type was not used on any of the test cases</td>
<td>-Hospital</td>
<td>-Hospital</td>
<td>-Hospital</td>
<td>-Hospital</td>
</tr>
</tbody>
</table>

Note: Abbreviations are as defined in Chapter 2 Decision Tables
in other cases they disagree. In cases where the two agree, the PDSS tables incorporate these rules. In cases where they disagree, the author has interpreted the knowledge to develop the rule. Thus, in some cases the PDSS tables follow the literature's recommendation and in other cases follows the experts' recommendation. This may be an oversimplification because in certain instances the literature had conflicts as did the experts.

The PDSS decision tables (Tables 4.1, 4.2) and the literature review tables (Tables 2.3, 2.5) have several differences. The PDSS decision tables lists four organizational structures and contract strategies while the literature review tables list six organizational structures and contract strategies. Two of these, the Design/Manage and Owner Construction organizational structures are eliminated from the PDSS decision tables due to the lack of project data for these two structures. Likewise, the PDSS tables combine the three cost-plus contract variations into one. No significant difference was noted in the literature or by the experts between the three.

Additionally, there are several differences involving the project risk factors. The PDSS tables list the project risk factors in order of importance as determined by the experts. The literature review tables list all the risk factors as determined from the literature and are in no particular order. The PDSS tables also combine project scope and complexity and separate the "team" into "owner" and "others" for the reasons mentioned in the previous chapter.

Lastly, the right column of each PDSS table includes a project composite risk recommendation and a ranking within each category for the respective organizational structures and contract strategies. Refer to the respective tables for any differences contained within the tables.
The bottom row in each table, titled "Typical Applications," include project types that were successfully predicted by the model that the experts believe are applicable.

4.3 THE PDSS MODEL

The PDSS Decision Trees are the model which the owner would use to make a project delivery selection decision (i.e., completing activities #2 and #3 in Figure 4.1). It is left up to each individual owner to determine the values of each project risk factor (i.e. critical, experienced, etc.). The PDSS Decision Tables provide rules to help evaluate the respective organizational structures and contract strategies. The tables, however, only compare one critical risk factor to an organizational structure and contract strategy. In order to account for the presence of several risk factors operating concurrently on a project, the PDSS Decision Trees (see Figures 4.2 to 4.7) consider the risk factors in order of importance, as stated by the experts.

Although several trees are shown, only two—an organizational structure tree and a contract strategy tree—will apply in selecting a delivery system. First, choose the delivery system activity desired, an organizational structure (Figure 4.2) or contract strategy (Figure 4.5). Secondly, determine the project characteristics of the current project, well defined (Figures 4.3 or 4.6) or poorly defined (Figures 4.4 or 4.7). Lastly, choose the tree which matches the delivery system activity desired and current project characteristics. Proceed through this tree with the other risk factor values to obtain the recommended project organizational structure or contract strategy.

4.4 USING THE MODEL

The critical project risk factors are listed in order of importance from left to right on each node. The user begins at the first node, project characteristics, and progresses through the tree by selecting the appropriate response for each risk factor. After
Figure 4.2 The PDSS (Organizational Structure) Model
Figure 4.3 The PDSS (Organizational Structure) Model for Well Defined Projects
Figure 4.4 The PDSS (Organizational Structure) Model for Poorly Defined Projects
Figure 4.5 The PDSS (Contract Strategy) Model
Figure 4.6 The PDSS (Contract Strategy) Model for Well Defined Projects
Figure 4.7 The PDSS (Contract Strategy) Model for Poorly Defined Projects
selecting the appropriate response for the last node, cost, a project organizational structure or contract strategy is recommended. Again, it is left to the user’s judgment to determine the appropriate project risk factor value. Figures 4.8 and 4.9 illustrate this procedure for a sample project. The data was provided by one of the experts and it describes the project referenced in Chapter 1. The project is a 100,000 ft\(^2\) multi-use building being built for a large, experienced owner. The budgeted project cost is approximately $8 million with a duration of 30 months.

**Step 1. Determine the Project Risk Factors**

- **Job Characteristics:** the project scope is poorly defined; the project is complex.
- **Time:** time is of the essence or critical.
- **Owner Experience:** the owner is experienced.
- **Team Experience:** the team is inexperienced.
- **Quality:** the specified quality level is above industry standard.
- **Cost:** cost is always important and in this case it is critical.

**Step 2. Select the Project Organizational Team**

Begin at the Project Characteristics node and proceed through the decision tree with the data obtained from Step 1.

- **Job Characteristics:** choose the poorly defined branch.
- **Time:** choose the critical branch.
- **Owner Experience:** choose the experienced branch.
- **Team Experience:** choose the inexperienced branch.
- **Quality:** choose the above industry standard branch.
- **Cost:** choose the critical branch.
Figure 4.8 Selecting the Organizational Structure for a Sample Project
Figure 4.9 Selecting the Contract Strategy for a Sample Project
**PDSS Recommendation:** Construction Management (Agency) project organizational structure

**Step 3. Determine the Project Contract Strategy**

Use the same project risk factors from Step 1. This assumes the risk factors did not change since selecting the organizational structure. The factors may change if the organization is selected early in a project's life and the construction contract is selected later in the design phase. If a change occurs, use the new risk factors.

**PDSS Recommendation:** Cost-Reimbursable (GMP) payment terms

For this particular project the PDSS recommends a *Construction Management (Agency)* organizational structure and a *Cost-Reimbursable (GMP)* contract. The owner selected a *Traditional* organizational structure and a *Fixed-Price (Lump Sum)* contract strategy. The project finished $3 million over budget and 6 months behind schedule. The other test cases are presented in the next chapter.

### 4.5 CONCLUSION

This chapter presented the Project Delivery Selection System (PDSS) model. It illustrates the selection of a project organizational structure and contract strategy for a given set of project risk factors. Chapter 5 tests the model on numerous projects with different project risk factors.
CHAPTER 5

TESTING THE PROJECT DELIVERY SELECTION SYSTEM (PDSS)

This chapter describes the testing process for the Project Delivery Selection System (PDSS). The purpose is to determine if there is a link between the selection of a project's organizational structure and contract strategy, using the PDSS model, and a project's success or failure. Twenty-two projects are tested with a wide range of project risk factors, organizational structures, and contract strategies.

5.1 PROJECT DESCRIPTIONS

The 22 projects that were studied fell into two categories: those projects provided by the experts, and those projects that served as the basis for the Critical Project Success Factor (CPSF) research [Sanvido, 1990].

Seven pairs of projects (14 total) were provided by the experts. Each pair were projects that the experts felt were their best and worst projects. These are referred to as the "Expert Projects." The projects had a wide range of project risk factors, all types of organizational structures, and different contract strategies. It is important to remember that the PDSS model was partly developed from the experts' responses to the questionnaire, not the specific data from these projects. The "Expert" projects are tested to determine the impacts of the critical project risk factors when they operate concurrently on a project. Table 5.1 illustrates the project data for these projects.
<table>
<thead>
<tr>
<th>Project #</th>
<th>Project Type</th>
<th>Project Data</th>
<th>Project Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Initial)</td>
<td>(Final)</td>
</tr>
<tr>
<td>*EB1</td>
<td>Hospital</td>
<td>330,000 ft²</td>
<td>within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$52 million</td>
<td>one month late</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36 months</td>
<td>quality met</td>
</tr>
<tr>
<td>*EB2</td>
<td>Hospital</td>
<td>280,000 ft²</td>
<td>$1 million under</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$26 million</td>
<td>6 months ahead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36 months</td>
<td>excellent team</td>
</tr>
<tr>
<td>*EB3</td>
<td>Manufacturing Plant</td>
<td>220,000 ft²</td>
<td>within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.5 million</td>
<td>on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 months</td>
<td>quality met</td>
</tr>
<tr>
<td>*EB4</td>
<td>Laboratory</td>
<td>500,000 ft²</td>
<td>within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10 million</td>
<td>on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24 months</td>
<td>quality met</td>
</tr>
<tr>
<td>*EB5</td>
<td>Research Building</td>
<td>57,000 ft²</td>
<td>within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$6.5 million</td>
<td>on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 months</td>
<td>quality met</td>
</tr>
<tr>
<td>*EB6</td>
<td>Emergency Care Facility</td>
<td>90,000 ft²</td>
<td>$450,000 under</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$15 million</td>
<td>1 month ahead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 months</td>
<td>quality met</td>
</tr>
<tr>
<td>*EB7</td>
<td>Hospital</td>
<td>350,000 ft²</td>
<td>within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$60 million</td>
<td>on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36 months</td>
<td>quality met</td>
</tr>
</tbody>
</table>
Table 5.1 (continued)

| **EW1** | Hospital | 130,000ft² | $200,000 over | 14 months late |
| **EW2** | Convention Center | 1.4 million ft² | $260 million | 24 months behind |
| **EW3** | Research Center | 50,000ft² | $3.5 million | 4 months behind |
| **EW4** | Office Building | 300,000ft² | $6 million | 6 months behind |
| **EW5** | Multi-use Facility | 71,000ft² | $8 million | 5 months behind |
| **EW6** | Prison | 90,000ft² | $3 million | 6 months behind |
| **EW7** | Hospital | 330,000ft² | $8 million | 12 months behind |

* Denotes a successful project according to the experts.

** Denotes an unsuccessful project according to the experts.
The project number nomenclature distinguishes the "best" from the "worst" projects (i.e., EB1-Expert Best 1, EW2-Expert Worst 2, etc.). The risk factors for each project can be found in Appendix B. The expert projects are separated into "best" and "worst" data tables with the respective project risk factors listed for each job.

Four pairs of projects (eight total), similar in scope, were tested from the CPSF projects (Sanvido 1990). A project pair is comprised of two similar projects, one successful and one unsuccessful. The projects were primarily high risk jobs with a wide range of risk factors. The actual organizational structure and contract strategy, however, are primarily Construction Management (G.C.) and Guaranteed Maximum Price respectively. Table 5.2 illustrates the project data for these projects. The risk factors for these projects can also be found in Appendix B.

Table 5.2 CPSF Project Data

<table>
<thead>
<tr>
<th>Project #</th>
<th>Project Type</th>
<th>Project Data (Initial)</th>
<th>Project Data (Final)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPSF1</td>
<td>Hospital</td>
<td>• 330,000 ft²</td>
<td>• within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• $21 million</td>
<td>• on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 16 months</td>
<td>• quality met</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• excellent team</td>
</tr>
<tr>
<td>*(H1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF3</td>
<td>Hospital</td>
<td>• 59,000 ft² (new)</td>
<td>• within budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 59,000 ft² (add.)</td>
<td>• on time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• $18.8 million</td>
<td>• quality met</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 20 months</td>
<td>• good contract</td>
</tr>
<tr>
<td>*(R1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Code</td>
<td>Project Type</td>
<td>Square Feet</td>
<td>Cost</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>CPSF5</td>
<td>Computer Center</td>
<td>400,000 ft²</td>
<td>$43 million</td>
</tr>
<tr>
<td>*(O1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF7</td>
<td>Hospital</td>
<td>300,000 ft²</td>
<td>$45 million</td>
</tr>
<tr>
<td>*(H3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF2</td>
<td>Hospital</td>
<td>130,000 ft²</td>
<td>$23.1 million</td>
</tr>
<tr>
<td>**(H2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF4</td>
<td>Office Renovation</td>
<td>1.1 million ft²</td>
<td>$28.2 million</td>
</tr>
<tr>
<td>**(R2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF6</td>
<td>Corporate Headquarters</td>
<td>110,000 ft²</td>
<td>$17 million</td>
</tr>
<tr>
<td>**(O2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPSF8</td>
<td>Hospital</td>
<td>92,000 ft²</td>
<td>$23 million</td>
</tr>
<tr>
<td>**(H4)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Denotes a successful project according to the CPSF study
** Denotes an unsuccessful project according to the CPSF study.

Note: Project Number nomenclature: (CPSF1-Critical Success Factor Project 1, R1-CPSF study nomenclature)
5.2 PROJECT DATA

Data was collected for the above listed projects. It includes a determination of the project risk factors and a comparison of the actual project delivery system with that predicted by the PDSS. The comparison of the actual delivery system with that recommended by the PDSS is shown in Table 5.3 ("Expert" Projects) and Table 5.4 (CPSF Projects). The respective project risk factors are shown in Appendix B. The projects are again separated into "best" and "worst" projects. The actual project delivery system is listed under "Actual Organizational Structure" and "Actual Contract Strategy." The recommended PDSS delivery system is listed in the remaining two columns.

The delivery system activities which were not accurately predicted by the PDSS are shown in bold in the tables. It is expected that the actual delivery system will match the PDSS' recommendation in the successful projects. Likewise, it is expected that the delivery systems will not match in the unsuccessful projects. Cases in which these situations do not apply are highlighted in bold in the tables.

<table>
<thead>
<tr>
<th>Project #</th>
<th>Project Type</th>
<th>Actual Organizational Structure</th>
<th>Actual Contract Type</th>
<th>PDSS Recommendation (Organization)</th>
<th>PDSS Recommendation (Contract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB1</td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC</td>
<td>GMP</td>
</tr>
<tr>
<td>EB2</td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC or D/B</td>
<td>GMP</td>
</tr>
<tr>
<td>EB3</td>
<td>Manufacturing Plant</td>
<td>D/B</td>
<td>CPF</td>
<td>TD or D/B</td>
<td>LS</td>
</tr>
<tr>
<td>EB4</td>
<td>Laboratory</td>
<td>TD</td>
<td>LS</td>
<td>TD or CMA</td>
<td>LS</td>
</tr>
</tbody>
</table>
Table 5.3 (continued)

<table>
<thead>
<tr>
<th>EB5</th>
<th>Research Building</th>
<th>TD</th>
<th>LS</th>
<th>TD</th>
<th>LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EB6</td>
<td>Emergency Care Facility</td>
<td>CMA</td>
<td>LS</td>
<td>CMA or CMGC</td>
<td>GMP or CPF</td>
</tr>
<tr>
<td>EB7</td>
<td>Hospital</td>
<td>TD</td>
<td>LS</td>
<td>TD or D/B</td>
<td>LS</td>
</tr>
<tr>
<td>EW1</td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC or CMA</td>
<td>GMP</td>
</tr>
<tr>
<td>EW2</td>
<td>Convention Center</td>
<td>*CMA, TD *</td>
<td>**GMP, LS</td>
<td>CMA</td>
<td>GMP</td>
</tr>
<tr>
<td>EW3</td>
<td>Research Center</td>
<td>D/B</td>
<td>CPF</td>
<td>CMA or D/B</td>
<td>CPF</td>
</tr>
<tr>
<td>EW4</td>
<td>Office Building</td>
<td>TD</td>
<td>LS</td>
<td>CMA or CMGC</td>
<td>GMP</td>
</tr>
<tr>
<td>EW5</td>
<td>Multi-use Facility</td>
<td>TD</td>
<td>LS</td>
<td>CMA</td>
<td>GMP</td>
</tr>
<tr>
<td>EW6</td>
<td>Prison</td>
<td>TD</td>
<td>LS</td>
<td>D/B or CMGC</td>
<td>GMP</td>
</tr>
<tr>
<td>EW7</td>
<td>Hospital</td>
<td>TD</td>
<td>LS</td>
<td>CMA</td>
<td>GMP or LS</td>
</tr>
</tbody>
</table>

Table 5.4 Delivery System Comparison (CPSF Projects)

<table>
<thead>
<tr>
<th>Project #</th>
<th>Project Type</th>
<th>Actual Organizational Structure</th>
<th>Actual Contract Type</th>
<th>PDSS Recommendation (Organization)</th>
<th>PDSS Recommendation (Contract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPSF1 <em>(H1)</em></td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>D/B or CMGC</td>
<td>GMP</td>
</tr>
</tbody>
</table>
Table 5.4 (continued)

<table>
<thead>
<tr>
<th>CPSF2 <strong>(H2)</strong></th>
<th>Hospital</th>
<th>CMGC</th>
<th>***GMP, CPF</th>
<th>Don't Build</th>
<th>Don't Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPSF3 <em>(R1)</em></td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC or CMA</td>
<td>GMP</td>
</tr>
<tr>
<td>CPSF4 <strong>(R2)</strong></td>
<td>Office</td>
<td>CMGC</td>
<td>GMP</td>
<td>Don't Build</td>
<td>Don't Build</td>
</tr>
<tr>
<td>CPSF5 <em>(O1)</em></td>
<td>Computer Center</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC or CMA</td>
<td>CPF or GMP</td>
</tr>
<tr>
<td>CPSF6 <strong>(O2)</strong></td>
<td>Corporate Headquarters</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMA or D/B</td>
<td>CPF or GMP</td>
</tr>
<tr>
<td>CPSF7 <em>(H3)</em></td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMGC</td>
<td>GMP</td>
</tr>
<tr>
<td>CPSF8 <strong>(H4)</strong></td>
<td>Hospital</td>
<td>CMGC</td>
<td>GMP</td>
<td>CMA</td>
<td>GMP</td>
</tr>
</tbody>
</table>

* Denotes a successful project.
** Denotes an unsuccessful project

5.3 RESULTS USING THE PDSS

This section will examine the results of using the PDSS on the Expert and CPSF projects. The PDSS was deemed successful if a "match" was obtained between the actual delivery system and the PDSS recommendation for the successful projects. Likewise, the PDSS was also successful if there was not a "match" between the actual delivery system and the PDSS recommendation for the unsuccessful projects.

Exceptions are highlighted in bold in Tables 5.3 and 5.4.
As shown in table 5.3 the PDSS accurately predicted the outcome of the Expert projects. Overall, the PDSS accurately predicted 12 out of 14 organizational structures and 10 out of 14 contract strategies. More specifically, for the "best" projects, the correct organizational structure was predicted in all cases while 5 out of 7 contract strategies were successfully predicted. For the "worst" projects the PDSS correctly predicted 5 out of 7 organizational structures and contract strategies.

The PDSS accurately predicted projects with the presence of both a high and low number of critical project risk factors. The number of critical project risk factors on projects accurately predicted, ranged from a high of 5 to a low of 2. Appendix B shows that the "best" projects had fewer critical risk factors present than the "worst" projects. The "best" projects averaged just over 2 factors present with a range from 1 to 4 while the "worst" projects averaged over 3 factors present with a range from 2 to 5. The model was slightly more accurate in predicting, or experts were better with projects with a "low" number of existing project risk factors.

Take, for example, project EW3, a "worst" project. The PDSS did not accurately predict the organizational structure nor the contract strategy for this project. As shown in Appendix B the project scope was poorly defined, time was "of the essence," the owner was inexperienced, the quality specified was above industry standard, and cost was critical. Clearly, the experienced team had a difficult task.

As shown in table 5.2 the PDSS accurately predicted the outcome of the CPSF projects. Overall, the PDSS accurately predicted 8 of 8 organizational structures and 6 out of 8 contract strategies. This data was further broken down into "successful" and "unsuccessful" projects, as defined by the CPSF study. In this study "success" or "failure" was determined by a combination of project goal attainment, degree of team cohesion, and team satisfaction. Each of the team members was interviewed in terms
of this criteria. Appendix B lists the respective project risk factors for the "successful" and "unsuccessful" projects.

The PDSS accurately predicted projects with the presence of both a high and low number of critical project risk factors. The number of critical project risk factors on projects accurately predicted ranged from a high of 5 to a low of 2. Appendix B shows that the "successful" projects had fewer critical risk factors present than the "unsuccessful" projects. The "successful" projects averaged exactly 3 factors present with a range from 2 to 4 while the "unsuccessful" projects averaged over 4 factors present with a range from 3 to 5.

Considering all projects, the model was slightly more accurate in predicting projects with a "low" number of existing project risk factors. As was explained, the "best" and "successful" projects had fewer critical risk factors present than the "worst" and "unsuccessful" projects respectively. The model was also slightly more accurate in predicting the former type projects as well as a project's organizational structure. Lastly, it can be inferred that the PDSS is only as accurate as the experts who provided the project data.

5.4 ANALYSIS OF PDSS RESULTS

In an attempt to explain the model's failure, in certain cases, further analysis is needed. Tables 5.5 and 5.6 present the risk profiles of the Expert projects and CPSF projects in which the PDSS was unsuccessful. A failure of the PDSS was occurred when there was a "match" between the actual delivery system and the PDSS recommendation for successful jobs or there was a "match" between the actual delivery system and the PDSS recommendation for unsuccessful jobs.
Table 5.5 Risk Profile of Expert Projects not Accurately Predicted by the PDSS

<table>
<thead>
<tr>
<th>Project #</th>
<th>Scope</th>
<th>Time</th>
<th>Owner</th>
<th>Team</th>
<th>Quality</th>
<th>Cost</th>
<th>Failed PDSS Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>*EB3</td>
<td>well</td>
<td>not</td>
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<td>experienced</td>
<td>above</td>
<td>critical</td>
<td>Contract</td>
</tr>
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<td>standard</td>
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<tr>
<td>*EB6</td>
<td>poorly</td>
<td>critical</td>
<td>inexperienced</td>
<td>experienced</td>
<td>above</td>
<td>not</td>
<td>Contract</td>
</tr>
<tr>
<td></td>
<td>defined</td>
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<td></td>
<td></td>
<td>standard</td>
<td>critical</td>
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</tr>
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<td>not</td>
<td>inexperienced</td>
<td>experienced</td>
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<td>critical</td>
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</tr>
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<td>experienced</td>
<td>inexperienced</td>
<td>industry</td>
<td>not</td>
<td>Contract</td>
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<td>standard</td>
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</table>

Denotes a successful project.

Denotes an unsuccessful project.

Table 5.6 Risk Profile of CPSF Projects not Accurately Predicted by the PDSS

<table>
<thead>
<tr>
<th>Project #</th>
<th>Scope</th>
<th>Time</th>
<th>Owner</th>
<th>Team</th>
<th>Quality</th>
<th>Cost</th>
<th>Failed PDSS Element</th>
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<td>Critical</td>
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<td></td>
<td>critical</td>
<td></td>
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<td>experienced</td>
<td>inexperienced</td>
<td>standard</td>
<td>critical</td>
<td>Contract</td>
</tr>
</tbody>
</table>

* Denotes a successful project.

** Denotes an unsuccessful project.
On project EB3, a "best" project, the PDSS recommended a Lump Sum contract. The actual contract was a Cost Plus Fee. A "tighter" contract was recommended because of the fact that an inexperienced, cost conscious owner of a well defined project would best be served by this contract type. The only justification for a cost-plus fee contract may be the fact that this was a complex project with a higher specified quality level. The project, however, was not so complex nor the quality level so high that they adversely impacted the project scope. This suggests that the model may be accurate in this case but other factors were present that made this a successful project.

On project EW1, a worst project, the PDSS recommended the same organizational structure and contract strategy that was chosen. With a poorly defined project and with a need to fix the price for an inexperienced owner, a Construction Management (GC) organizational structure and Guaranteed Maximum Price contract was recommended. The fact that the team was experienced also lends itself to this structure and contract strategy. Why did it fail? Data from the project indicates that the owner's representative changed shortly before construction and the architect had his own views on the what exactly the GMP included. Although the experience level of both owner's was about the same the original owner and contractor had a good working relationship. The same could not be said for the new owner's representative. The architect believed the GMP contract included a higher specified quality than that which the contractor was prepared to deliver. The end result was an uncooperative team resulting in constant problems throughout the job. Whether the PDSS recommendation was correct or not is not the issue here. The point is that other factors may have been responsible for this job's failure.

It can be said that project EW3 was a "high" risk project. Five of the six critical risk factors were present. The contractor said this was the "worst" job he had ever seen.
let alone participate in. The owner's representative changed and essentially no one could agree on anything. The PDSS recommended the most favorable structure and contract type to compensate for the degree of risk involved. According to the contractor the change in owners resulted in numerous scope changes and he was not willing to compensate the contractor for what the latter believed he was entitled. The project was completed in 1989 and of this writing the contractor has not been paid in full. This case also illustrates that other factors may be responsible for a project's failure.

On project CPSF 8, an "unsuccessful" project, the PDSS recommended a Guaranteed Maximum Contract, the same contract chosen for this project. Since the scope was poorly defined and the owner was experienced a case could be made for using a Cost-Plus Fee contract. A GMP contract was recommended because the team was inexperienced and cost was critical. No one wants to pay for an inexperienced team's mistakes. This was the first project of this type for the architect who also did not have any backup staff. Additionally, the mechanical/electrical designers had staff with low experience who turned over frequently. This, plus the fact that the mechanical subcontractor was a poor performer, hindered the project. Choosing a Cost-Plus Fee contract in this instance could have resulted in even greater problems than those experienced. Again, other factors may have been responsible for this project's failure. Similar cases could be made for the other situations in which the PDSS was not successful.

A successful application of the PDSS is examined next. On project EB1, the PDSS matched the actual organizational structure and contract strategy. This project was deemed a success by the parties involved even though it finished almost two months late. The general consensus was that the chemistry of the team was a major factor in the project's success. In fact, it seems team cohesion plays a big role in project success and the lack of team cohesion plays a big role in project failure.
Clearly, just as there may be other factors (besides the project risk profile, organizational structure, and contract strategy) responsible for a job's failure, there may be other factors responsible for a job's success. The PDSS recommends an organizational structure and a contract strategy which allows the players to behave as a team - two of the Critical Success Factors recommended by Sanvido (1990). With this stated it is understood that selecting the proper PDSS elements may contribute to job success and selecting the improper PDSS elements may lead to job failure. Further research is needed in determining the "other" factors and their impact on a project's outcome.

Lastly, one may infer that the PDSS as well as the unsuccessful projects had some problems given the presence of certain risk factors, and that, the PDSS and the successful projects were successful given the absence of these factors. From a detailed examination of all the data, no such conclusion can be reached. The PDSS was successful and unsuccessful on different projects with the same risk factors present or absent. Likewise, projects with the same risk factors present were both successful and unsuccessful. This is not to say that the absence or presence of certain critical risk factors is not a factor in a project's success or failure. There was just not enough conclusive evidence to make such a generalization. Again, the only conclusion that can be reached from the data is that projects with a lower number of critical risk factors were, in general, more successful than projects with a high number of risk factors. This as well as other recommendations for further research are explained in the next chapter.
5.5 CONCLUSION

This chapter presented the results of the testing procedure. The PDSS model was accurate in predicting the outcome of many different project types with different risk profiles, organizational structures, and contract strategies. In certain instances, the model was unsuccessful in correctly predicting a project's outcome. Reasons for this were examined and the conclusion reached that other factors, beyond the scope of this research, may be responsible for not only the failure of projects but their success as well. Nevertheless, the PDSS is accurate in recommending the proper organizational structure and contract strategy for a wide range of projects. The following chapter summarizes this study and makes recommendations for additional research in this area.
CHAPTER 6

CONCLUSION

This chapter compares the research results to the original objectives. Limitations of the PDSS as well as areas for further research are discussed.

6.1 COMPARING RESEARCH RESULTS WITH OBJECTIVES

Chapter 1 identified an important decision facing owners: the need to select the proper organizational structure and contract strategy for a project. It was noted that this is a difficult task given the numerous project delivery options and virtually infinite number of project risks. The problem facing owners, and the industry in general, is that there is no method available to help those who must make these important selection decisions. This study set out three objectives for solving the problem. These objectives and the subsequent research to accomplish each are discussed below.

6.1.1 Identifying the Critical Project Risk Factors Affecting Project Delivery

This first objective involved identifying the most common project risk factors affecting project delivery and, of these, which ones are the most critical. Reviewing the current literature identified the most common risk factors and shed some light on the most critical ones. Interviewing the experts confirmed the relative importance of each of the identified factors and their impact on the selection of an organizational structure and contract strategy.
6.1.2 Provide a Model to Assist With Project Delivery Decisions

After identifying the critical project risk factors it was necessary to develop a model which accounted for their interaction on a project and which recommended an appropriate organizational structure and contract strategy. This was accomplished through the use of decision trees (the model) which recommended an organizational structure and contract strategy for a variety of unique project situations.

It was noted in Chapter 4 that the model was developed from an application of rules, obtained from the literature and experts, and intuition - the latter being applied in cases where the literature and/or experts were silent or had a disagreement. The end result of the model development process is a tool an owner can use to make project delivery decisions for a wide range of project situations.

6.1.3 Testing the Model

This objective was accomplished by testing the model on twenty two projects with a wide range of project characteristics and risk factors. The project data came from experts, who identified their "best" and "worst" projects, and from another study which identified reasons for "successful" and "unsuccessful" projects. The projects used a variety of project organizational structures and contract strategies.

The results indicated that the model was extremely successful on all types of projects with many different risk factor combinations. It was slightly more accurate on successful projects and also in predicting the project organizational structure.

A discussion of the results in Chapter 5 included reasons for the model's success or failure. It was noted that other factors, beyond the scope of this research, may contribute to a project's outcome. These include owner satisfaction, and the degree of team cohesion. Nevertheless, the model offers insight into a project organizational structure and contract strategy for a variety of project situations.
6.2 LIMITATIONS OF THE PDSS

Several limitations of the PDSS are identified below:

1. The scope of the interview process was limited. Only seven subjects were interviewed. Although the key players (i.e., owner, architect, constructor) are included, the number of these subjects is few.

2. The model does not account for "average" responses. A risk situation is either critical or not, experienced or inexperienced, and so forth. In many instances an "average" situation will apply.

3. The model recommends an organizational structure and contract strategy based on the identified critical project risk factors. Assuming these are correct, the model excludes the presence of "other" factors which may affect a project's outcome.

6.3 AREAS FOR FUTURE RESEARCH

Through the course of this study, and based on the model's limitations, several areas requiring further research are identified. These are discussed next.

1. The PDSS is limited in that it was developed using a small number of expert sources. More respondents should be interviewed to determine if the critical factors, as stated, are accurate and are placed in their proper order of importance in the model.

2. More study is needed in measuring the critical risk factors. Specifically, when is one considered "experienced," or when is time considered "of the essence?" In the study, these judgments were made by the experts, who also felt there that there is a big variance on the meanings of these terms.

3. The PDSS separated the "owner" from the other "team" members. This was done largely on the recommendation of the experts who felt that although all are on the
same "team," they are separate players. Likewise, further splitting the "team" into architect, and constructor may add to the model's precision.

4. In this study it was noted that the combination of several risk factors may have an impact on a project's outcome. For example, is a project more likely to fail if the critical factors of scope, cost, and time or scope, owner experience and quality, etc. are present at the same time? Likewise, is a project more likely to succeed if certain risk factor combinations are absent?

5. Also mentioned in the study was the fact that "other" factors, besides the identified critical factors, may affect a project's outcome. For example, the degree of involvement of the players in the planning process, or the risk allocation of the specific contract clauses may be factors that also determine project success. Additionally, does the presence of incentive or liquidated damage clauses have any impact on the PDSS? Further study could examine the impact of project success of these "other" factors.

6. In this age of automation it may be helpful to computerize this model. To make it worthwhile, however, the relative importance of each of the risk factors to each other must be known. For example, on a scale of 1 to 10 does project characteristics rate an eight or a nine, is time a 5.5 or a 6, etc.? With these certainty factors in hand an expert system could be developed. It is no coincidence that this is listed last, because we as an industry are far from reaching this point.

6.4 SUMMARY

The PDSS is a simple and accurate tool owners can use to make important project delivery selection decisions. It accounts for project risk and recommends a project organizational structure and contract strategy for many unique project situations.
It was found through testing to be an accurate predictor of project success or failure.

By properly using the model, prior to the selection of a project team and contract strategy, an owner could increase the chances of project success and limit the chances of project failure.
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Appendix A

PDSS PROJECTS STUDY

QUESTIONNAIRE
**Introduction:**

The intent of this questionnaire is to build a set of rules which identify project risks and their impact on the selection of an organizational structure and contract strategy. The survey consists of some background information followed by questions on Project Risk, Project Organizational Structures, and Project Contract Strategies. In the last section you will be asked to identify PDSS characteristics [i.e. risk, team, contract] as they apply to successful and unsuccessful jobs.

**1. General**

- INTERVIEW DATE
- COMPANY
- POC:
- EXPERIENCE OF POC
  - years in "PDSS" business
  - # of projects picked PDSS for
  - projects
    - type construction [residential, institutional/commercial, industrial, infrastructure/heavy]
    - location [urban, rural]
    - avg. cost
    - avg. duration
    - avg. size [ft.2]
    - projects you're familiar with usually have [cost, time, quality, other_______] as the primary concern.
2. Risk

2.1 This section will help in developing a complete listing of project risk factors. It is understood that one or more of the mentioned factors may apply on a project at a given time. As best you can try to treat each question independently.

2.2 • how do you measure risk?

2.3 • what risk factors do you generally consider?

  2.3.1 - which ones are the most critical?

2.4 • what are the risk impacts if:

  2.4.1 - completion time is shorter/longer than the average job?

  2.4.2 - cost is greater/less than avg. job?

  2.4.3 - quality is greater/less than avg. job?

  2.4.4 - job technical complexity [i.e. how] increases/decreases?

  2.4.5 - project scope [i.e. what] is clear/unclear?

  2.4.6 - the execution strategy remains the same/changes

  2.4.7- job size [ft^2] increases/decreases from avg. job?

  2.4.8 - team's experience on similar projects is:

    2.4.8.1 - above avg.[more than 4]
2.4.8.2 - avg.[2-3]
2.4.8.3 - below avg.[0 or 1]

2.5 - are there any other risk factors which you consider critical?
2.5.1 - what do you do if they increase/decrease?

3. Organizational Structure

3.1. This section will help in determining how project risks affect the selection of a project organizational structure [i.e. the team]. It is understood that one or more risk factors may affect the team's selection, however, try to treat each question independently.

3.2. • what structure do you normally use [i.e. "avg" risk]

3.2.1 - why?
3.3. • does risk impact on your selection of a particular organizational structure?

3.3.1 - how?
3.4. • what do you consider to be the one or two most critical risk factors in selecting an organizational structure?

3.5. • structure used if risk is "high"

3.5.1 - critical risk factor/s

3.5.2 - other considerations

3.6 • structure used if risk is "low"

3.6.1 - deciding factor/s
3.7. • what organizational structure do you select when:

3.7.1 - time is of the essence?

3.7.2 - why?

3.7.3 - cost is the main concern?

3.7.4 - why?

3.7.5 - quality is the main concern?

3.7.6 - why?

3.7.7 - job technical complexity [i.e. how] increases/decreases?

3.7.8 - project scope [i.e. what] increases/decreases?

3.7.9 - job size increases/decreases from the avg. job?

3.7.10 - team experience on similar projects is:

3.7.10.1 - above avg. [more than 4]

3.7.10.2 - average. [2 or 3]

3.7.10.3 - below average [0 or 1]

3.8. • are there any other risk factors which cause you to change your organizational structure selection?

3.8.1 - what do you do if they increase/decrease?
4. Contracts

4.1 This section will help in determining how project risks affect the selection of a project contract strategy. It is understood that one or more risk factors may affect the selection of the most appropriate contract, however, try to treat each question independently.

4.2 • what type contract do you normally use [i.e. "avg" risk]

4.2.1 - why?

4.3 • does risk impact on your selection of a particular contract strategy?

4.3.1 - how?

4.4 • contract used if risk is "high"

4.4.1 - critical risk factor/s

4.4.2 - other considerations

4.5 • contract used if risk is "low"

4.5.1 - deciding factor/s

4.6 • what do you consider to be the one or two most critical risk factors in selecting a contracting strategy?

4.7 • what contract strategy do you select when:

4.7.1 - time is of the essence?

4.7.2 - why?
4.7.3 - cost is the main concern?

4.7.4 - why?

4.7.5 - quality is the main concern?

4.7.6 - why?

4.7.7 - job technical complexity [i.e. how] increases/decreases?

4.7.8 - project scope [i.e. what] increases/decreases?

4.7.9 - job size increases/decreases from the avg. job?

4.7.10 - team experience on similar projects is:

4.7.10.1 - above avg. [more than 4]

4.7.10.2 - average [2 or 3]

4.7.10.3 - below avg. [0 or 1]

4.8 - are there any other risk factors which cause you to change your contract strategy selection?

4.8.1 - what do you do if they increase/decrease?
5. Case Studies

5.1 In this section you will be asked to give details on projects that you believe benefitted/were hindered from the selection of the appropriate/inappropriate organizational structure and contract strategy.

5.2 General [Best Job]

5.2.1 • owner
5.2.2 • constructor
5.2.3 • type construction
5.2.4 • location
5.2.5 • project name
   5.2.5.1 - size [ft.²]
   5.2.5.2 - duration [on time?]
   5.2.5.3 - cost

5.3. Risk [Case Study - Best Job]

5.3.1 • on this project the risk was high/medium/low

5.3.2 • on this project the critical risk factors were:

5.3.3 • the project risks were/were not considered in the selection of an organizational structure & contract strategy. [i.e. risk profile established, more formal planning, outside experts called in...]

5.3.4 • how did the project risks affect the PDSS?
5.4 Organizational Structure [Best Job]

5.4.1 • the project organizational structure selected was:

5.4.1.1 - why?

5.4.2 • what risk elements impacted on this decision?

5.5. Contract Strategy [Best Job]

5.5.1 • the project contract strategy selected was:

5.5.1.1 - why?

5.5.2 • what risk elements impacted on this decision?

5.5.3 • was there anything else which made this a successful project?

5.6. General [Worst Job]

5.6.1 • owner • a/e

5.6.2 • constructor

5.6.3 • type construction

5.6.4 • location

5.6.5 • project name

5.6.5.1 - size [ft.²]

5.6.5.2 - duration [on time?] 

5.6.5.3 - cost

5.7 Risk [Case Study - Worst Job]

5.7.1 • on this project the risk was high/medium/low

5.7.2 • on this project the critical risk factors were:
5.7.3 • the project risks were/were not considered in the selection of an organizational structure & contract strategy. [i.e. risk profile established, more formal planning, outside experts called in...]

5.7.4 • how did the project risks affect the PDSS?

5.8 Organizational Structure [Worst Job]

5.8.1 • the project organizational structure selected was:

5.8.1.1 - why?

5.8.2 • what risk elements impacted on this decision?

5.9 Contract Strategy [Worst Job]

5.9.1 • the project contract strategy selected was:

5.9.1.1 - why?

5.9.2 • what risk elements impacted on this decision?

5.9.3 • was there anything else which made this an unsuccessful project?
Appendix B

PROJECT DATA
### Table B.1  Expert Project Data ("Best" Projects)

<table>
<thead>
<tr>
<th>Project #</th>
<th>Scope/Complexity</th>
<th>Time</th>
<th>Owner Experience</th>
<th>Team Experience</th>
<th>Quality</th>
<th>Cost</th>
<th># of Risk Factors</th>
<th>Organization Match?</th>
<th>Contract Match?</th>
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<td>industry standard</td>
<td>not critical</td>
<td>2</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
# Table B.3  CPSF Project Data ("Successful" Projects)

<table>
<thead>
<tr>
<th>Project #</th>
<th>Scope/ Complexity</th>
<th>Time</th>
<th>Owner Experience</th>
<th>Team Experience</th>
<th>Quality</th>
<th>Cost</th>
<th># of Risk Factors</th>
<th>Organization Match?</th>
<th>Contract Match?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPSF1 (H1)</td>
<td>well defined/ non-complex</td>
<td>critical</td>
<td>inexperienced</td>
<td>experienced</td>
<td>industry standard</td>
<td>critical</td>
<td>3</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CPSF3 (R1)</td>
<td>poorly defined/ complex</td>
<td>not critical</td>
<td>inexperienced</td>
<td>experienced</td>
<td>industry standard</td>
<td>critical</td>
<td>3</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CPSF5 (O1)</td>
<td>poorly defined/ complex</td>
<td>critical</td>
<td>experienced</td>
<td>experienced</td>
<td>above standard</td>
<td>critical</td>
<td>4</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CPSF7 (H3)</td>
<td>poorly defined/ complex</td>
<td>not critical</td>
<td>experienced</td>
<td>experienced</td>
<td>above standard</td>
<td>critical</td>
<td>2</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Project #</td>
<td>Scope/Complexity</td>
<td>Time</td>
<td>Owner Experience</td>
<td>Team Experience</td>
<td>Quality</td>
<td>Cost</td>
<td># of Risk Factors</td>
<td>Organization Match?</td>
<td>Contract Match?</td>
</tr>
<tr>
<td>-----------</td>
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<td>---------</td>
<td>------</td>
<td>------------------</td>
<td>---------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>CPSF2 (H2)</td>
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<td>critical</td>
<td>inexperienced</td>
<td>inexperienced</td>
<td>industry standard</td>
<td>critical</td>
<td>4</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CPSF4 (R2)</td>
<td>poorly defined/complex</td>
<td>critical</td>
<td>inexperienced</td>
<td>inexperienced</td>
<td>industry standard</td>
<td>critical</td>
<td>5</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CPSF6 (O2)</td>
<td>poorly defined/complex</td>
<td>critical</td>
<td>inexperienced</td>
<td>experienced</td>
<td>industry standard</td>
<td>not critical</td>
<td>5</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>CPSF8 (H4)</td>
<td>poorly defined/complex</td>
<td>not critical</td>
<td>experienced</td>
<td>inexperienced</td>
<td>industry standard</td>
<td>critical</td>
<td>3</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>