



PROJECT DELIVERY AND CONTRACT STRATEGY

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A Report to
Construction Industry Institute
The University of Texas at Austin

Under the Guidance of
CII Research Team 165
Project Delivery and Contract Strategy

CII Research Report 165-12
September 2001

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Printed in the United States of America.

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EXECUTIVE SUMMARY

Project delivery and contract strategies (PDCS) define the roles and responsibilities of the parties that are involved in a capital project, and how the project owner pays for services. They define the owner's framework for managing project execution. An efficient framework would facilitate project success. Establishing such framework for a project would be achieved when the most suitable project delivery and contract strategy is selected.

In place of informal assessments that is the current practice, a structured methodology has been developed for making this important project management decision by project owners. This procedure focuses on the owner's overall project objectives and the project execution environment, and incorporates a quantitative assessment of twelve integrated PDCS alternatives in a decision support tool.

The procedure includes a decision support tool in the form of a simple *Excel*™ workbook, for performing the PDCS selection analysis. This analysis involves identifying the selection factors that are relevant to the project under consideration (decision objectives that are aligned with the owners' overall project objectives and other success parameters for the particular project), assigning preference weights to those factors to reflect their priority on that project, and obtaining aggregate scores from the spreadsheet. The aggregate scores are computed as sum-product functions of the user-defined preference weights, and pre-determined relative effectiveness values. The higher the aggregate score, the more suitable the PDCS alternative is, in theory, for the subject project. The results of the decision support tool are reviewed in a final decision making step.

Responses obtained during testing and validation of this procedure and tool have already shown that it:

- Expands the set of PDCS alternatives that are available to owners in the decision-making process.
- Is an improvement over current practices.
- Identifies optimal solutions.
- Enhances insight into the problem of selecting a project delivery and contract strategy for a capital project.
- Harmonizes delivery systems with contract strategies and relates these to the owner's project objectives.
- Constitutes a useful decision support system.
- Provides a defensible rationale for PDCS selection.

CHAPTER I

INTRODUCTION

1.1 Research Subject

Capital facility projects are executed as compositions of numerous design, procurement and construction tasks, performed by different service providers. The way the constituent tasks in a particular project are packaged for execution, and the types of services that the owner retains for the execution of those tasks define the delivery system for that project. Complimentary to the delivery system is the contract strategy adopted for the project. The contract strategy defines how the owner pays for the services rendered by service providers in the execution of a particular project. This implicitly defines the allocation of financial risks between the owner and the service providers.

In the owner's management of capital facility projects, the project delivery system and contract strategy together provide the framework for organizing project execution. An efficient framework will facilitate project success and selecting such an efficient framework would be achieved when the most suitable combination of delivery system and contract strategy is selected. It had been shown that such efficiency could reduce project cost by an average of 5% (*Contractual*, 1982). Consequently, the selection of the project delivery system and contract strategy is a fundamentally important decision made in the project development stage. It has implications for the execution of all phases of the project.

The owner plays a pivotal role in the life of a capital project, more so in the early stages of the project when it has the responsibility for performing several critical business-related functions. Successful performance of these functions directly impacts the owner's perception of project success. Selection of a project delivery system and contract strategy for a project is one of the functions that the owner performs during project development. This is therefore an owner's decision problem.

Each party that is involved in a capital project has its own project objectives. Research has shown that the level to which the owner's objectives are successfully achieved depend on the extent to which the objectives of the owner and those of the service providers are harmonized (Construction Industry Institute, 1997). The project delivery system and contract strategy are vehicles for achieving this harmony. At the project development stage, the owner has the opportunity to adopt the approach that is most harmonious for that project.

The project delivery system defines the parties in the project and implicitly assigns roles and responsibilities to the various parties. The contract strategy defines how the parties are to be paid for the services that they render in the execution of the project. Combined, an integrated project delivery and contract strategy answers the questions, "Who does what and when, and how will they be paid?"

1.2 Background

A critical success factor in the execution of capital projects is the development of the project execution plan. Central to this project execution plan is the project delivery system and contract strategy. A suitable project delivery system would optimally assign roles and responsibilities for the performance of project activities, including defining their sequencing. A suitable project delivery system would be one that facilitates the optimal performance of these activities, with respect to the owner's project objectives.

Hitherto, there was no standardized, broad-based set of documented project delivery systems, applicable to a wide range of project types. The Construction Industry Institute (CII) sought to correct the situation by commissioning this research study, with the aim of defining a broad array of project delivery systems and contract strategies, and developing a decision procedure and tool for selecting a combined approach from these sets, for each particular project.

Project tasks and the service providers that execute them can be put together in many different ways to deliver capital projects. The number of approaches that can be fashioned to deliver projects is virtually unlimited, especially if all the possible options and variations are included. However, in fundamental terms, it is possible to reduce the set of approaches to a manageable list (AIA, 1976). From an owner's perspective, one such fundamental view of projects would involve grouping the numerous tasks into the three primary activity phases of engineering/design, procurement, and construction, and defining service providers as designers, constructors, suppliers or management agents.

Bowers and Anderson (2001) present a standardized and comprehensive set of integrated project delivery system and contract strategy alternatives, developed during the first phase of this research project sponsored by CII. Three distinct characteristics used to define project delivery and contract strategies are:

- The sequencing of the three main project phases of design, procurement, and construction, relative to each other.
- The service providers that are contractually retained by the owner, to form the project team, and the primary functional relationships within the project team.
- The type of compensation approach that is used for each contractual relationship.

Figure 1.1 shows an example of an integrated project delivery and contract strategy (PDCS) defined on the basis of these three characteristics. The PDCS alternative depicted in Figure 1.1 is an overlapped delivery system, with the owner contracting primarily with a

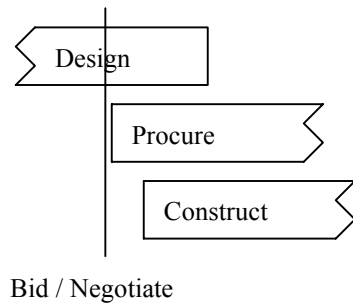
designer and a Construction Manager-at-Risk (who takes on responsibilities and risks for construction) for the execution of a project.

The contract strategy (or compensation approach) is closely related to the project delivery system. The contract strategy defines how the owner pays for services rendered by the service providers in the project team, as shown in Figure 1.1. The contract strategy implies the allocation of financial risk among the parties to the contract. Ideally the contract strategy should be chosen such that financial risks are equitably distributed among the parties. Incentives may also be designed and incorporated in the contract strategy, to encourage the commitment of all parties to the attainment of the owner's project objectives (Howard & Bell, 1998).

A total of eleven unique, integrated, Project Delivery and Contract Strategy (PDCS) alternatives were identified and validated through a data collection and analysis exercise (Bowers and Anderson, 2001). The eleven validated PDCS alternatives were then evaluated from a selection analysis perspective, and re-constituted into twelve alternatives in the decision procedure and tool that is presented in this report.

Construction Manager-at-Risk delivery system, PDCS 06

Phase Sequence: Overlapped sequence of design and construction
(Procurement begins during design)



Project Team Relationships:

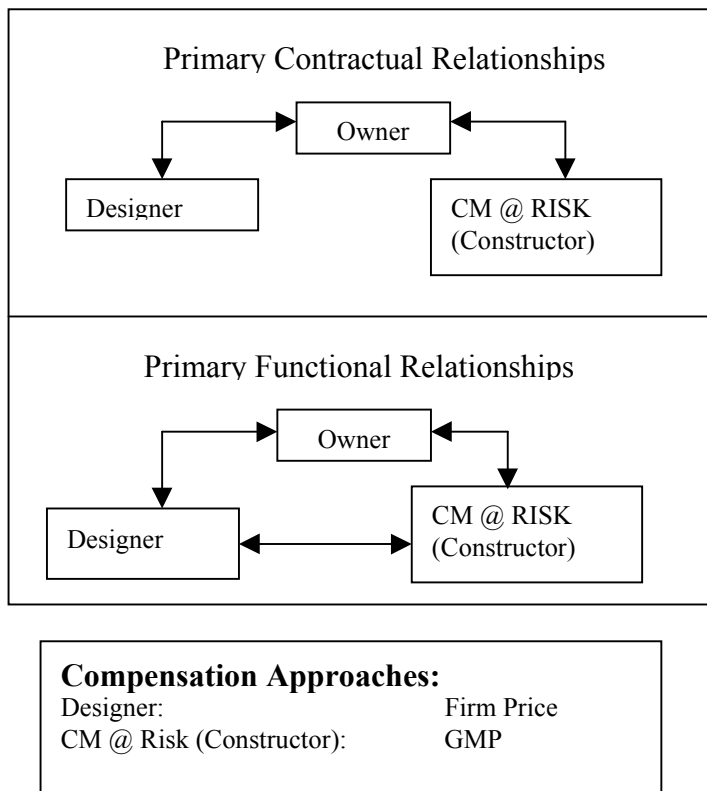


Figure 1.1: Sample definition of an integrated project delivery and contract strategy (PDCS)

Arriving at the most suitable project delivery and contract strategy for a project is one of the major decision problems that need to be properly solved in order to achieve project success. However, decision problems in the management of capital projects are mostly approached informally. Typically, decision-makers are confronted with many decisions. Due to time constraints, most of these decisions have to be made informally. This is common in the management of any type of enterprise, but the efficient approach is to separate the more critical decisions for formal analysis (LaValle, 1990).

Previous research established that the decisions made in the early stage of project execution have the highest influence on project life cycle costs (Construction Industry Institute, 1995). These critical decisions should be subjected to structured analytical processes. However, data obtained in the course of this research showed that one of such decisions was overwhelmingly being made on the basis of informal, holistic assessments. Out of twenty-five responses received to a questionnaire administered to member companies of the Construction Industry Institute, only two companies had access to a detailed and quantitative procedure for selecting project delivery systems. This information is presented in Figure 1.2.

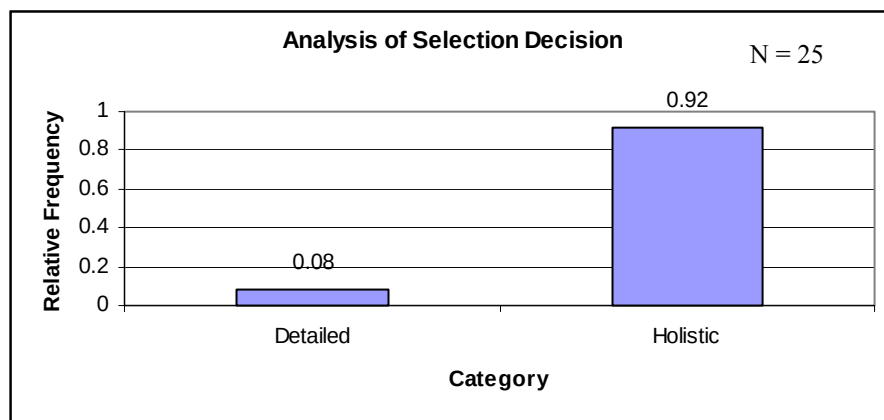


Figure 1.2: Detailed vs. holistic approach in selection of project delivery and contract strategy for capital projects

This chart shows clearly that the informal, holistic assessment is, by far, the more common approach in making this decision. In the cases of the two companies that indicated having access to a detailed, analytical tool, the tools were proprietarily developed for exclusive use. Lack of access to a widely available tool would be one of the reasons for the prominence of informal, holistic assessments in making this decision.

The structured decision-making process has several benefits over the informal, holistic approach. The decision analysis process involves the decomposition of the decision problem into smaller problems that the decision-maker can focus on separately. The solutions to the smaller problems are aggregated using established techniques and an optimal course of action can then be easily evaluated. French (1983) states “unguided human judgement is susceptible to many failings. In particular, a number of studies have shown that holistic assessments give weight to fewer value attributes than a guided multi-attribute approach.”

The structured decision process may lead to the same decision as an informal process but the structured process provides the decision-maker with greater insights into the decision problem. Keeney (1982) states: “Decision analysis will not solve a decision problem, nor is it intended to. Its purpose is to produce insight and promote creativity to help decision-makers make better decisions.”

Although decision analysis may not produce the “solution” to a decision problem, Goodwin and Wright (1991) state that the results of an analysis can be regarded as being “conditionally predictive.” This means that the analysis will show the decision-maker what should be done, given the judgements provided during the course of the analysis. Decision analysis is, therefore, more suitably applied in decision support systems, as opposed to decision-making tools. In addition to providing “conditionally predictive” results and insight into the decision problem, the decision analysis process provides the decision-maker with a defensible rationale for selecting a particular option.

1.3 Problem Statement

Hitherto, the focus of research efforts and developmental work in project management had been on the activities of the engineering, procurement and construction phases of project execution, where the bulk of project funds are expended. Project development activities, which typically involve relatively lower expenditures, have generally not received as much attention. This is borne out by the dearth of leading-edge procedures for tackling project development problems like PDCS selection.

Research data showed that in some cases, proprietary processes had been developed for in-house application. Such proprietary procedures could not have been developed on the basis of industry-wide, broad-based research. In practically all cases, informal procedures are used in selecting a delivery approach and contract strategy. These decisions are made without a careful consideration of all the alternatives that are available, or all the factors that are relevant to the decision, and their interrelation. There is oversimplification of the decision problem, with attendant inaccuracies. Clear-cut objectives and critical measures of project success are not identified at the onset of the project, making it difficult at the completion of the project to evaluate the extent to which project success was achieved, beyond overall schedule and cost performance.

Measurement is a precursor to control. Conventionally, an item that can not be measured can not be controlled. Quantification is, therefore, a step towards efficient control and management of any parameter. The lack of quantification in the current procedures for selecting project delivery and contract strategy for a project impedes efficiency in the selection process, and its outcome. Also, the level of accurate information available to a decision-maker directly impacts the quality of decision-making. An efficient, better-informed decision-making process would, therefore, be preferable over a process that is based on less information.

This research sought to address these problems and presents a procedure for making better-informed decisions on selecting the project delivery system and contract strategy for a capital project.

1.4 Research Objectives

The overall objective of this research was captured in the mission statement that reads: **To produce a process to assist in selecting a contract delivery strategy to optimize owner's project objectives.** A coordinated, comprehensive and structured methodology was required for solving a problem that was largely unstructured before this research. The methodology would support consistently high quality in project decision making.

This research was performed in two phases. In the first phase, validated sets of project delivery and contract strategy alternatives and selection factors were defined. In the second phase, a decision procedure and tool were developed, based on the variables defined in the first phase. This research report presents the details of the activities in the second phase of the research project.

Application of decision analysis techniques to solving decision problems has been proved to result in better-informed decision-making, and produce methodologies for quality decision making. Therefore, the objective of this phase of the research was pursued through an investigation of the possibility of successful application of a decision analysis technique in a generalized solution procedure for selecting a delivery system and contract strategy for a capital project. This investigation involved seeking answers to the following questions:

- How would a generalized solution process that can be applied to different capital projects be modeled?
- What variables would be required to implement the solution process?

- Could the variables be defined in a form that would be suitable for application in a decision analysis technique?
- Could values be defined for the variables with sufficient accuracy?
- Would a solution process developed on these bases produce reliable results and enhance the quality of decision making?

In order to answer these questions and achieve the overall objective of the research successfully, specific tasks (or sub-objectives) that needed to be accomplished successfully in this phase of the research were identified. These were:

1. Evaluate different decision analysis methods for solving the decision problem, and select an appropriate method for a decision support tool.
2. Determine the set of alternative project delivery systems and the factors relevant to the decision problem.
3. Evaluate viability of different project scenarios, as a basis for screening the variables in selection of project delivery systems.
4. Define attributes for the decision factors, and attainment levels (called relative effectiveness values) for the project delivery alternatives.
5. Develop a decision making procedure and support tool that will guide decision-makers through the process of making better-informed decisions in PDCS selection, including contract strategy selection.
6. Validate the procedure and tool.

A flowchart of this phase of the research is presented in Figure 1.3. Detailed discussion of these sub-objectives and their corresponding tasks shown in the flowchart in Figure 1.3 is presented in Chapter II, Section 2.2.

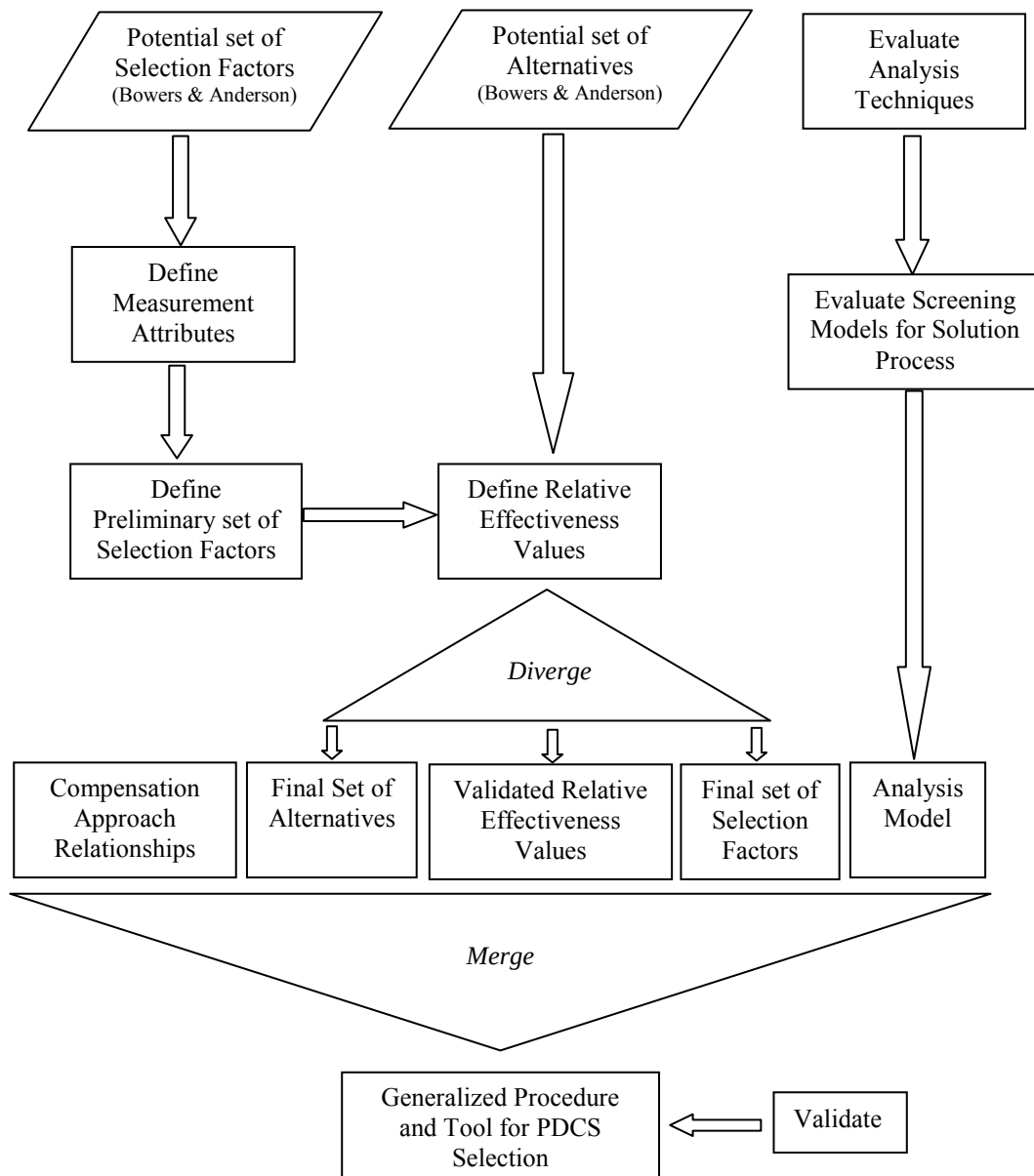


Figure 1.3: Flowchart of overview of research process

The overall objective of facilitating better-informed selection of project delivery system and contract strategy for capital facilities projects was achieved when:

- Broadened, comprehensive sets of the decision parameters (alternatives, factors, and objectives) were provided in the decision making process and the decision support tool. Responses from data collection on current practices indicated that such comprehensive sets of decision parameters were not available previously.
- A coordinated and structured framework in the form of a decision analysis-based system was provided for navigating through the decision-making process. A generalized model of the decision problem was developed, relating generic forms of owners' overall project objectives and selection factors to project delivery and contract strategies in a quantitative manner. An integration of delivery system selection with contract strategy selection was achieved. Responses from data collection on current practices indicated that such structured framework was not available previously.
- Research-based performance measures of the alternatives in relation to the selection factors, applicable across a wide range of projects, were provided in the decision making process and decision support tool. Responses from data collection on current practices indicate that such performance measures were not available previously.
- Responses obtained during validation of the procedure and tool developed through this research confirmed that the procedure and tool represent an improvement over current practices. It was confirmed that they reveal optimal solutions and enhance insight into the selection of delivery systems and contract strategies for capital projects.

1.5 Organization of Report

This report consists of eight chapters. In Chapter I, an introduction of the research subject and its relation to capital facility projects is presented. This was followed by a discussion of the problem that was identified, and the research objective that was set, towards addressing the problem statement. Detailed, measurable sub-objectives were also defined for the research.

In Chapter II, a review of literature related to the subject of the research is presented. The literature review covered the areas of decision support tools, project delivery systems and contract strategies, and decision analysis techniques. The literature review was followed by a presentation of highlights of the research activities that were employed to address each of the sub-objectives that were identified in Chapter I.

An exposition of decision analysis techniques relevant to the selection of project delivery systems and contract strategies is presented in Chapter III. The relevant techniques had been identified from review of literature in Chapter II. Two case study examples were analyzed with each of the selected decision analysis techniques. The process of analyzing the two case study examples revealed the tasks that needed to be performed in research, for developing a generalized procedure and tool for project delivery system and contract strategy selection. The solution process of each technique, as revealed by the analysis of the two case study examples was also the basis for comparing the techniques for suitability in this case. From the comparison, an analysis technique was selected for the selection tool.

From the analysis of the case study examples in Chapter III, it was noted that well-defined global sets of delivery system alternatives and generic selection factors would facilitate the development of a procedure and tool for general application. The results of a previous research in this area were used as the starting point for defining these global sets. In Chapter IV, this source data was further refined and adapted for application in a selection analysis tool. The delivery system alternatives obtained from the previous research were slightly expanded. Measurement attributes were defined for the acquired selection factors. On the basis of the measurement attributes, some selection factors were merged, or confirmed to have no impact on delivery system selection.

The analysis of the case study examples in Chapter III also revealed the need to collect data and establish measures of the performance of the delivery systems alternatives in the global set with respect to the selection factors in the global set. These performance measures, which

were labeled relative effectiveness values, are presented in Chapter V. The procedures followed in the development of these numbers and the analysis performed on, or with them are presented in this chapter.

In order to simplify some of the user's tasks in using the selection procedure and tool that would be developed, models that would simplify those tasks were investigated in Chapter VI. A process for screening and reducing the number of variables to be considered in any particular analysis was investigated. Sensitivity analysis that would aid the interpretation of the results of the analysis, and simplify user's tasks in this regard into a simple step was performed in Chapter VI. Integration of contract strategy selection into the delivery system selection process was also investigated and presented in this chapter.

An overview of the selection procedure and tool developed from this research is presented in Chapter VII. The results of the validation of the procedure and tool are also presented and discussed in this chapter.

Summary, conclusions, and recommendations are presented in Chapter VIII.

CHAPTER II

LITERATURE REVIEW AND RESEARCH METHODOLOGY

2.1 Literature Review

2.1.1 Decision-Making and Decision Support Systems

Decision-making is a central function of management. This is a much-recognized fact that has led to studies and the continuing development of decision aids in diverse areas of management. Henriksen and Traynor (1999) studied the problem of evaluating and selecting research and development projects for execution. A decision support tool was developed using Microsoft Excel to aid decision-making in the management of research and development organizations. A combined additive and multiplicative algorithm was developed to evaluate research proposals over a set of criteria, and then incorporate funding requests in the scoring model.

Mitropoulos and Tatum (2000), and Wilson, Ramamurthy, and Nystrom, (1999) studied decision-making in the area of technology adoption decisions. Mitropoulos and Tatum (2000) used case studies to create a model of the rate of diffusion of 3D CAD technology in the construction industry. The interactions between organizational characteristics, industry factors and technological factors in technology adoption decisions were presented, for a better understanding of the innovation mechanism. Meanwhile, Wilson, Ramamurthy, and Nystrom, (1999) studied technology adoption decisions from the context of imaging technology in the hospital industry. Their findings also supported the climate – innovation link, and included attributes of measure on the parameters of radicalness and relative advantage, on 68 technologies in the hospital imaging technology area. An organization's preference for radicalness would indicate the technological option that would be adopted by such an organization and the relative advantage that might accrue from such a decision.

In the area of capital facility project management, selection problems have been the subjects of numerous studies and the focus of several decision support tools. The problem of selecting a construction method for underground pipeline construction was the object of the study carried out by Ueki, Haas and Seo (1999) while Spainhour, Mtenga and Sobanjo (1999) developed a decision support system for selection and installation of crash attenuators in highway construction. Ziara and Ayyub (1999) developed a methodology for effective use of available resources in housing project developments in countries with limited resources, while McIntyre and Parfitt (1998) proposed a decision support system for residential land development selection.

In some cases, the study of selection problems focussed on defining the alternatives that should be considered in specific subject areas, or defining the appropriate selection criteria for particular selection problems. Included in this category are the studies carried out by Miller, Garvin, Ibbs, and Mahoney (2000), Jiang and Klein (1999), Chua, Kog and Loh (1999), Griffith, Gibson, Hamilton, Tortora and Wilson (1999), and Uhlik and Eller (1999). In all, significant work has been performed, and continues to be developed in this area.

2.1.2 Project Delivery Systems and Contract Strategies

As already discussed, project delivery system and contract strategy provide the framework for the execution of a capital facility project as a business venture. From a business perspective, this framework is similar to the organizational structure of a commercial entity. The decision that confronts owner's project managers is determining the framework that is most suitable for achieving the owner's project objectives. Typically, this involves selecting one approach from a list of prescribed alternatives. But the quality of a decision can be no better than the quality of the alternatives that are presented to the decision-maker (Souder, 1980). It is therefore imperative that a most comprehensive set of high-quality alternatives forms the basis of any decision support tool or process. These alternatives need to be defined from the perspective of owners, to address project objectives and issues that are important to owners.

Project delivery systems and contract strategies have sufficiently gained the attention of the American Institute of Architects (AIA, 1976) and the Associated General Contractors of America (Dorsey, 1997) to warrant special publications on the subject. These publications present extensive treatment of project delivery and contract strategies, but from the perspectives of the service providers, not the owners who actually make the decision. The publications were aimed primarily at providing information to service providers on the implications of different project delivery and contract strategies to their operations and businesses. In view of this, the PDCS alternatives and selection factors included in these documents were limited to only those that have different implications for the service providers.

The delivery systems that were presented and discussed in these documents are shown in Table 2.1. It is worth noting that the AIA (1976) alternatives were defined on the basis of the sequencing of design and construction activities while Dorsey (1997) defined the alternatives on the basis of the different types of service providers that constitute the project team. Nonetheless, four out of five of the alternatives in both cases are similar and all the alternatives are relevant in a decision making process for owners. The alternatives, however, do not constitute the full complement of alternatives that should be available in an owner's decision-making process.

Table 2.1: Project delivery systems in AIA and AGC publications

AIA (1976)	Dorsey (1997)
Design-Award-Build Approach	Design-Bid-Build Approach
Design-Award-Build Approach with Construction Consultant as General Contractor	At-Risk Construction Manager
Design-Award-Build Approach with Construction Consultant as Construction Manager	Agency Construction Manager
Overlapped Design and Construction: Phased Approach	Program Manager
Integrating Design and Construction: Design-Build Approach	Design-Build

Selection of project delivery systems and contract strategies also continues to receive the attention of researchers. Notable works in this area include the publications by Gordon (1994) and Alhazmi and McCaffer (2000).

Gordon (1994) proposed a two-part selection-by-elimination process consisting of:

1. Organization selection

A three-step process is proposed for selecting one out of six delivery alternatives (including Build-Operate-Transfer) based on project drivers, owner drivers, and market drivers. The project drivers and owner drivers each consist of five factors while the market drivers consist of three factors.

The first elimination of alternatives is carried using a chart to eliminate inappropriate methods based on assessment of the project drivers. The project drivers were defined as time constraints, flexibility needs, pre-construction service needs, design process interaction, and financial constraints. Further elimination is carried out by assessing the owner drivers which are construction sophistication, current capabilities, risk aversion, restriction on methods, and other external factors. Finally, the remaining alternatives are evaluated on the basis of market drivers and an organization method is selected. The market drivers were defined as availability of appropriate contractors, current state of the market, and package size of the project.

In the organization selection process, some of the six organization methods are combined with fixed price or reimbursable contracts. This generated a set of nine alternatives for consideration in the first elimination step. Final selection of contract type is carried out in the contract selection part of the process.

2. Contract selection

Four contract types were defined for the contract between the owner and the construction contractor. First, the risks involved in the project are assessed, considering the finality and completeness of the construction documents at the time of award. One out of the four contract

alternatives is then selected on the basis of the desired allocation of risk between the owner and the contractor.

The procedure proposed by Gordon (1994) does not include a decision support tool but provides a good basis for the development of a comprehensive process and tool. It is limited in the alternatives presented, and the consideration of the elimination criteria. The alternatives can assume only dichotomous values with respect to each elimination criterion.

Alhazmi and McCaffer (2000) proposed three primary classes of procurement systems comprising twelve procurement methods (project delivery systems) as follows in Table 2.2:

Table 2.2: Delivery systems proposed by Alhazmi and McCaffer (2000)

Separated and Cooperative Procurement Methods	Integrated Procurement Methods	Management Oriented Procurement Methods
Traditional method	Design and Build	Management contracting
Two stage tendering	Package deals	Design and manage
Negotiation method	Turnkey	Construction management
Serial contracts	Develop and construct	
Cost reimbursable contracts		

Inspection of these delivery alternatives did not reveal a consistent approach that was used to define the alternatives. “Cost reimbursable contracts,” “two stage tendering,” and “negotiation method” do not conform to a consistent definition of delivery systems and should not have been included in the set of alternative delivery systems. Furthermore, the traditional method and design and manage method would be indistinguishable in an owners’ selection process and should be combined. In both methods, the project team would consist of the owner, the designer and the constructor, and the sequence of the activity phases would be similar. The only discernable difference between these two approaches would be the slightly increased role of the designer in the construction phase in design and manage approach, over the relatively lower

role of the designer in the construction phase in the traditional approach. This difference is not fundamental and justification for using it to differentiate two alternatives could not be found. Similarly, the design and build method and the develop and construct method should be regarded as same in this context. The “two stage tendering” method may be better classified under the package deals method.

The process proposed by Alhazmi and McCaffer (2000) consists of four screening steps. The first three steps are used to eliminate some alternatives so that at the commencement of the fourth step, only a manageable number of alternatives are left to consider. In the fourth screening step, the analysis of the remaining alternatives is carried out based on the analytic hierarchy process (AHP) technique.

Implementation of the four screening steps proposed by Alhazmi and McCaffer (2000) was found to be arduous. Busy project managers and decision-makers would find the process very tasking to use. The procedure includes consideration of a total of forty-six selection criteria, twenty-five of which are classified under client needs. In the first screening step alone, all twelve alternatives are scored on a scale of 0 – 5 on each of twenty-one criteria that do not fall into the client needs category, to determine which alternatives are feasible for the project under consideration. In the second screening step, the benefits and limitations of each of the feasible alternatives are listed and compared. Based on this comparison, the feasible alternatives should be ranked and the higher-ranked alternatives taken to the third screening step for further analysis. However, the procedure for ranking the alternatives, or partitioning the ranked alternatives into higher-ranked and lower-ranked groups was not provided.

In the third screening step, a weighted evaluation of the surviving alternatives is carried out, based on consideration of the twenty-five criteria classified under client needs, to identify the optimum alternative. The twenty-five criteria are compared in pairs and manipulated through a series of steps, at the end of which scores are assigned on a scale of 1 to 10 to each factor, to represent the importance of that criterion to the project. Then, each of the remaining alternatives

is evaluated with respect to each of the twenty-five client needs' criteria and assigned a performance score on a scale of 1 to 5. A total score, computed as the sum of the products of performance scores and the assigned importance scores is obtained for each alternative. From this, the optimum alternative is presumed to be that with the highest total score.

The fourth screening step involves further analysis, this time with the use of the *Expert ChoiceTM* software, implementing the analytic hierarchy process. The alternatives that were categorized as excellent, very good or good at the end of the third step are further analyzed, based on consideration of all forty-six criteria. The hierarchical structure of a typical problem as presented by Alhazmi and McCaffer (2000) consisted of 83 nodes, without including the hierarchical level of the alternatives. Thus, if three alternatives were analyzed in the fourth screening step, 249 pairwise comparison matrices would need to be generated for analysis by the software. Experience with the *Expert ChoiceTM* software shows that such an exercise would be highly prone to errors, and the results may not be reliable. The time and effort required to complete such an exercise would also render it unattractive to the targeted users.

The process proposed by Alhazmi and McCaffer (2000) utilizes different facets of some decision analysis techniques. However, it does not appear to completely keep to all the principles of any of the techniques. The analysis process appears to be based on a hybrid of techniques. The process involves many complexities that may be avoidable. The process focussed more on numerical treatment, rather than enhancement of insight, thereby failing to capitalize on the real strength of decision analysis techniques. Furthermore, the listed selection criteria reflect the fact that the process was developed for public building projects only. Some criteria relevant to other project types were not included in the procedure. The complimentary subject of contract strategy selection was also not addressed in this procedure.

Sanvido and Konchar (1998) carried out a comparative study of three delivery system alternatives, namely design – bid – build, design – build, and construction management at – risk

in the general building environment. This comparative study was followed by a procedure for delivery system selection (Sanvido and Konchar, 1999).

The procedure proposed by Sanvido and Konchar (1999) includes an analytical selection process that appears to be flawed on three main counts. In the first case, the alternatives presented in the process were limited to only those three that were evaluated in the earlier research study (Sanvido and Konchar, 1998). Secondly, the selection factors included in the process reflected the fact that they were derived from the earlier study which looked at only one type of projects. Thus, alternatives and selection factors that are relevant to this and other project types were omitted in the selection process proposed by Sanvido and Konchar (1999).

Finally, the analysis approach included in the selection process proposed by Sanvido and Konchar (1999) did not appear to conform to established decision analysis theory. The analysis starts with a consideration of eight performance criteria. A scoring exercise is then implemented to identify the three most important criteria. The analysis then proceeds to a comparison chart that is provided. In the comparison chart, predetermined ratings of all three alternatives on each of five (out of eight) performance criteria is provided; pre-determined ratings of the alternatives on the remaining three performance criteria is provided graphically in a separate figure. A delivery system is selected by identifying the alternative that has the best rating on the three criteria identified as most important in the earlier scoring exercise.

Although the selection is treated as a multi-criteria selection exercise, provision is not made for harmonizing the selection across the three most important criteria. For example, if one alternative rates highest on the first selection criterion and a second alternative rates highest on the second selection criterion, while the third alternative rates highest on the third selection criterion, it would be impossible to identify the alternative that promises the best overall performance over the three selection criteria. A decision would have to be made on only one criterion. However, a more fundamental drawback in the procedure is the fact that one of the three alternatives completely dominates the remaining two over the set of performance criteria.

This alternative has the highest rating on all the criteria and is the one that would always be selected by this process. This negates the need for the selection exercise.

Other previous developments of decision tools to aid project managers and decision-makers in PDCS selection were the results of the efforts of business entities. The tools were developed as proprietary business processes for particular owners or a group of owners. In this category of tools are those developed by Flad & Associates (1994) for clients involved with projects of the general building type, and AIAG (1998) for owners involved with facilities development in the automotive industry. A review of these tools showed that the sets of alternatives and selection factors that are presented vary from one tool to the other. None of the tools presents what could be considered a full complement of alternatives and selection factors.

Flad & Associates (1994) identified four Team Structure Options (delivery systems) and seventeen selection factors in their decision tool whereas the AIAG (1998) process identified five alternatives and eight two-sided selection factors in their delivery system selection tool. The Flad & Associates (1994) process presents the alternatives and selection factors in a matrix format. A predetermined effectiveness rating is assigned to each alternative with respect to each selection factor. The effectiveness ratings range in value between 3 and 7. The user assigns an importance score, from 0 (not important) to 5 (highly important) to each factor to reflect the importance of the factor to the project. A sum of the products of importance score and effectiveness rating over all factors is computed for each alternative. The alternatives are rated on the basis of their total scores and the alternative with the highest total score is selected. A similar scoring matrix is provided for the analysis and selection of one out of four possible contract strategies for the construction contract.

The AIAG (1998) process also presents the alternatives and selection factors in a matrix format. Similarly, predetermined performance scores on a scale of 1 to 5 are assigned to each alternative with respect to each side of each of the eight, two-sided selection factors (16 unique factors). The process starts with the user assigning importance weights to each of the eight

factors. The weights are assigned as percentages, and all the weights must sum up to 100%. For each alternative, the performance score of that alternative with respect to a factor will be multiplied by the importance weight assigned to that factor, to obtain the criteria score. This is repeated for each alternative with respect to each factor in turn. For each alternative, the criteria scores are added up to obtain the delivery method score. The alternatives are then compared on the basis of the delivery method scores and the alternative with the highest score is selected.

The AIAG (1998) process provides for selection of one out of three contract strategies, for the main construction contract only. These contract strategies are fixed price, cost plus fee with guaranteed maximum price, and basic cost plus fee (without guaranteed maximum price). A “pricing options” table is provided in which each delivery system alternative is ascribed a predetermined rating of either poor, good, or best, with respect to each of the three contract strategies. Once the delivery system is selected using the delivery system selection matrix, the “best” contract strategy for that delivery system is identified and selected from the “pricing options” table.

Both the Flad & Associates (1994) and the AIAG (1998) processes are very simple and straightforward to use. This is a great advantage, considering the fact that the expected users of the tools are busy decision makers and project managers. The delivery system selection parts of the processes appear to have been founded on an established decision analysis technique, the Simple Multi-Attribute Rating Technique (SMART). However, closer examination shows that there are departures from the provisions of that analysis technique.

In the SMART technique, a well-defined procedure is recommended for evaluating the preference weights that the user assigns to each factor in the analysis. In the Flad & Associate (1994) and AIAG (1998) processes, this procedure is not followed. The Flad & Associate (1994) process represents the further departure from the prescribed procedure, with the use of importance factors on the scale of 0 to 5. Furthermore, in the Flad & Associate (1994) and

AIAG (1998) processes, the effectiveness ratings/performance scores are expressed on a scale different from that recommended in SMART, without any discernable justification.

In the two processes, the results of the analysis are treated as normative prescriptions. Such an approach is unsupported in theory (McCord and de Neufville, 1983). The results of the selection analysis only represent ordinal preferences and not value differences between the alternatives (French, 1983). Therefore, practical application of the technique would include incorporating the results of a sensitivity analysis in the final decision making. Such sensitivity analysis would examine the robustness of the results of the selection analysis to inherent inaccuracies in the value judgements upon which the analysis is based, and investigate the possibility of rank reversal. Such sensitivity analysis is not provided in these procedures; the results are interpreted as final and absolute.

In some cases, the alternatives and selection factors considered in both the Flad & Associates (1994) process and the AIAG (1998) process were the same. In such cases, it would be expected that the pre-determined effectiveness ratings and corresponding performance scores would be the same. This was not the case. However, despite the shortcomings identified in these tools, they provided a very useful starting point for the process and tool developed and presented in this report.

The variables in a selection problem include the decision alternatives, the selection factors and attributes, and estimates of the performance attainment of the alternatives on the selection factors. As with the alternatives, a wide disparity was observed in the existing decision tools in the definition of the relevant selection factors and attributes, and the performance attainment of the alternatives on the attributes of measure.

Objective empirical measures of the attainment of alternatives on different factors are practically impossible to determine for capital projects. Sanvido and Konchar, (1998) compared the performance of three delivery systems on the bases of cost, schedule and quality for general

building projects. In that study, indirect attributes of unit cost, cost growth, cost intensity, construction speed, delivery speed, schedule growth, turnover quality, system quality, and equipment quality were used as the metrics for comparison. The performances of each of the three alternatives with respect to each of these indirect attributes were then subjectively assessed through a data collection exercise.

Over the range of factors and delivery systems that may be relevant in a decision analysis tool for general application in the selection of project delivery systems for different types of capital projects, quantitative measures of performance attainment would not be obtainable. In practically all cases, the selection factors and the corresponding attributes of measure are qualitative. Quantified performance attainment would need to be assessed subjectively. This was reflected in all the tools and procedures that were reviewed, and would characterize the procedure and tool that is presented in this report.

2.1.3 Decision Analysis Techniques

Decision problems are classified either as decision problems under certainty or decision problems under uncertainty. From the names of the two categories, it is clear that certainty of events is the distinguishing factor. Decision problems could also be categorized as multi-objective, or single objective decision problems. Decision problems under uncertainty could be illustrated with the case of selecting a house for purchase, out of three available houses. Consider that the house to be selected would be the one with the most attractive property value at a time twenty years from the date of purchase. Obviously, the property value of a house twenty years into the future can not be determined with certainty, and probability-based estimates would be more appropriate in this selection analysis.

On the other hand, selection of a house for purchase based on the criteria of distance from known work place, and distance from a predetermined school would be an example of a decision problem under certainty. Assuming there are three alternative houses being considered, the distance from each house to the work place can be determined with certainty. Similarly, the

distance from each house to the school can be determined with certainty. In this case, the house to be selected would be the one that offers the best value in terms of the combination of distance from school and distance from work place.

The current practice in the selection of project delivery systems involves the consideration of multiple objectives in holistic assessments, with the alternatives assumed to have certain performance attainment levels with respect to the selection objectives. Thus, project delivery system selection is currently being treated as a multi-objective decision problem under certainty.

Analytical techniques for decision making have evolved over the years. These techniques attempt to decompose complex decision problems into smaller, more manageable, quantitative problems. Theoretical foundations, procedures, and algorithms for solving multiple objective mathematical programming problems were the focus of Multi-Criteria Decision-Making (MCDM) research in the 1970's. In the 1980's, the focus of research efforts shifted to the development of analysis packages to implement MCDM models on computers (Dyer et al, 1992). Presently, numerous commercial software packages are available which implement the different methodologies.

Multiple objective decision making methodologies that are currently in use include Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART), Analytic Hierarchy Process (AHP), Geometric Mean, Preference Cones, and Outranking Methods. A critical distinguishing factor among the various techniques is the role that uncertainties play in the evaluation of the alternatives. The consideration of uncertainties in the definition of the decision problem or elicitation of decision-maker's preferences adds a major complication to the solution process. This complication often undermines the quality of the information that is obtained from the decision-maker(s) and ultimately undermines the accuracy of the outcome of the analysis. Research has shown that such exercises are often riddled with inconsistencies in the inputs from the decision-makers (Bocherding et al, 1991). This has led to

several efforts to meet the challenges of lack of precision in the preferences and subjective probabilities of decision-makers (Dyer et al, 1992).

Few, if any, of the problems that decision-makers are confronted with in real life are defined by parameters that have absolutely certain values. Decisions are usually based on best estimates. It would therefore be most appropriate to use the probability-based multi-attribute utility theory with utility functions. If the problem parameters had certain values, then the more straightforward and probability-free value functions would be used in the multi-attribute utility theory analysis.

Although the probability-based multi-attribute utility theory is most appropriate in most cases, its application in real life has been fraught with complications that worsen geometrically with increasing number of objectives. In evaluating the practical usefulness of utility, Goodwin & Wright, 1991 state:

First, we have doubts about the practice adopted by some analysts of applying utility to decisions where risks and uncertainties are not central to the decision-maker's concerns. Introducing questions about lotteries and probabilities to these sorts of problems seem to us to be unnecessary. In these circumstances, the problem of trading off conflicting objectives is likely to be the main concern, and we would therefore recommend the approach of(value functions). In important problems which do involve a high level of uncertainty and risk we do feel that utility has a valuable role to play, as long as the decision maker is familiar with the concept of probability and has the time and patience to devote the necessary effort and thought to the questions required by the elicitation procedure. In these circumstances, the derivation of utilities may lead to valuable insights into the decision problem. In view of the problem associated with utility assessment, we should not regard the utilities as perfect measures and automatically follow the

course of action they prescribe. Instead, it is more sensible to think of the utility function as a useful tool for gaining a greater understanding of the problem.

If the decision-maker does not have the characteristics outlined above or only requires guidance on a problem, then it may not be worth eliciting utilities. Given the errors which are likely to occur in utility assessment, the derivation of values (as opposed to utilities) and the identification of the course of action yielding the highest expected value may offer a robust enough approach.

LaValle (1995) states that when the consequences of each available course of action are “almost” certain, much work can be eliminated, at little risk, by regarding each consequence as certain. Using such an approximation, the utility functions of multi-attribute utility theory are replaced by value functions derived from the certainty assumption. This approach has been applied successfully in solving many real-life decision problems, including selecting a site for nuclear power plants and the analysis of alternatives for the disposition of surplus weapons-grade plutonium (Dyer, Edmunds, Butler, and Jia, 1998). This simplified approach would be supported with a sensitivity analysis to evaluate the robustness of the result of the analysis.

As discussed earlier, current practice in selecting project delivery systems approaches the problem as a multi-objective decision problem under certainty. In light of the foregoing, such an approximation is justifiable and is worth adopting, in modeling the problem for decision analysis.

Selection problems with certainty assumptions are mostly analyzed using the methods of multi-attribute utility theory and analytical hierarchy process (Olson 1996). Therefore, analytical techniques that may be applied to the selection of project delivery systems would include the analytic hierarchy process (AHP), the classical multi-attribute utility theory (MAUT) with value functions, and the simple multi-attribute rating technique (SMART), a variant of the classical multi-attribute utility theory technique. In this research, these three approaches were evaluated

in detail, to determine the approach that is most suitable for selecting project delivery systems by practicing project managers and decision makers.

The decision process for solving selection problems is a multi-stage process, based on the decision analysis technique that is adopted. The steps involved in multi-attribute utility theory and the analytic hierarchy process are different, but the overall processes can be summarized as described by Keeney (1980) and presented below.

1. Identify the relevant alternatives
2. Define business and project objectives and environment.
3. Decompose objectives and environment into decision factors, and define attributes and preference weightings for each factor
4. Determine relative performance or attribute attainment for each alternative with respect to each decision factor.
5. Combine all parameters in an analysis model and obtain overall scores or ratings for all the alternatives.
6. Select the most suitable alternative on basis of overall score or rating, while incorporating a sensitivity analysis.

These represent the basic process steps adopted in modeling this decision problem. However, these steps apply only to the selection of project delivery systems and not the selection of contract strategies. Contract strategy selection is a single criterion selection problem under certainty, based on equitable allocation of financial risks among the two parties to each contract. This decision problem does not require a multi-criteria decision analysis, as does project delivery system selection. The single-criterion selection of contract strategies is discussed in Chapter VI of this report.

2.2 Research Methodology

The overall objective of this research and the constituent sub-objectives were presented in Chapter I, Section 1.4. The sub-objectives are repeated in the list below and the research methodology adopted to achieve each of the sub-objectives follows thereafter.

1. Evaluate different decision analysis methods for solving the decision problem, and select an appropriate method for a decision support tool.
2. Determine the set of alternative project delivery systems and the factors relevant to the decision problem.
3. Evaluate viability of different project scenarios, as a basis for screening the variables in selection of project delivery systems.
4. Define attributes for the decision factors, and attainment levels for the project delivery alternatives.
5. Develop a decision making procedure and support tool that will guide decision-makers through the process of making better-informed decisions in PDCS selection, including contract strategy selection.
6. Validate the procedure and tool.

2.2.1 Decision Analysis Techniques

Multi-attribute utility theory and the analytic hierarchy process are the two primary techniques for solving selection problems with multiple objectives (Olson, 1996). With increasing number of parameters, the mathematical solutions in these techniques become more cumbersome, making these processes particularly amenable to computer-based solutions. Several commercially available software packages have been developed based on these techniques (Olson, 1996).

In this research, Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART), and the Analytic Hierarchy Process (AHP) and their implementation software packages were evaluated for solving the project delivery system selection problem. These techniques were compared on the bases of:

1. The relative level of cognitive effort that would be required of decision-makers in using a decision support tool based on each technique.
2. The ability of the technique to enhance the decision-maker's insight into the decision problem.
3. The cost of acquiring the implementation software package.

With MAUT and SMART, simplicity of the analysis process is greatly enhanced by the adoption, where applicable, of linear single utility functions and additive aggregation formula. Such simplifying steps were investigated in the evaluation of the techniques.

The overall suitability of each of the techniques for selecting the project delivery system was assessed. Two case study examples were developed and analyzed, using each of the three techniques. The solutions and solution steps were presented at a workshop to a panel of practicing industry experts. The panelists were asked to identify the approach that would be most suitable in practice. The approach selected at the workshop was utilized in the development of the decision tool.

2.2.2 Comprehensive Sets of Alternatives and Factors

Bowers and Anderson (2001) present a validated and comprehensive set of integrated project delivery and contract strategy alternatives, defined from the owner's perspective, that are available and are in use in the construction industry. That research also presents a validated, comprehensive set of generic selection factors. The sets of validated alternatives and decision factors were further evaluated as inputs in a decision analysis process.

Delivery system alternatives were evaluated for uniqueness and domination. This was an iterative process that was related to the evaluation of the performance levels of the alternatives with respect to each selection factor. In the event that one alternative had the same vector of performance scores as another alternative over all the selection factors, the two alternatives would in essence be identical. In such a case, one of the two alternatives would be redundant and would not need to be included in the analysis. Alternatively, if one of the delivery system alternatives had a vector of performance scores that were lower in each and every case than the set of performance scores for another delivery system alternative, then the lower-scoring alternative is dominated by the higher scoring alternative. The dominated alternative would not need to be included in the analysis since it would be redundant.

Similarly, the selection factors were evaluated for uniqueness and ability to differentiate the delivery system alternatives. This evaluation was performed after the definition of attributes of measure for all the selection factors, as discussed later in Section 2.2.4. Uniqueness of each selection factor was evaluated by comparing the statement of the attribute of measure defined for each factor with those of other factors, by inspection. In the event that two or more factors had the same attribute of measure, only one of those factors would be retained while the others were dropped. The ability of the selection factors to differentiate the alternatives was evaluated by inspecting the performance levels of the alternatives on each factor. In the event that all the alternatives had the same performance level with respect to a selection factor, such a selection factor would be classified as non-differentiating, and eliminated from consideration in the selection analysis. In the same way, a selection factor with respect to which all the alternatives did not register a performance level would be classified as non-differentiating, and would also be eliminated from consideration in the selection analysis.

2.2.3 Decision Models

The number of decision variables that can be conveniently and accurately handled in a decision analysis process vary from one analysis technique to the other. From the variables defined by Bowers and Anderson (2001), there were a total of eleven delivery system

alternatives and thirty selection factors that might need to be presented to decision makers in a comprehensive decision process. Including all these variables in the analysis for every problem could make it difficult for decision-makers to accurately make the evaluations that would be required in the course of the analysis. Furthermore, such encumbered analysis would require much time and effort as to make the process inefficient, and unattractive to busy decision-makers.

The alternatives or selection factors that would be relevant to each decision problem should be subsets of the comprehensive or global sets. Therefore, the analysis model needed to be structured in such a way that only the variables that are relevant to each problem are presented in the analysis for that problem. Several approaches were evaluated to arrive at suitable analysis model for different types of projects.

A database containing data on 88 projects was set up. The data on each project included the delivery system that was used for the project, the primary objectives of the project in order of priority, the selection factors considered in informal decision making, in order of priority, the project type, and other project characteristics like budget cost and compensation approaches. Although statistically reliable correlation between project objectives and selection factors in the data set had not been obtainable (Bowers and Anderson, 2001), an investigation of project scenarios and associated selection factors and delivery systems was carried out.

The objective of the investigation was to identify subsets of delivery system alternatives and subsets of selection factors that may be predictably associated with particular project scenarios. Thus, for each defined project scenario, only the associated subset of delivery system alternatives and associated subset of selection factors would need to be considered in the selection analysis for projects that fit in that project scenario. The project scenarios were defined by a combination of project type and primary project objectives, to represent different classifications of projects. For example, combination of the project type “industrial” with