EVALUATION OF PROJECT DELIVERY METHODS FOR TRENCHLESS CONSTRUCTION

by

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ABSTRACT

EVALUATION OF PROJECT DELIVERY SYSTEMS

FOR TRENCHLESS CONSTRUCTION

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The need of today's construction whether it be residential, commercial or infrastructure is to cut costs while maintaining schedule, scope, and delivering the expected quality. This realization has brought to light the importance of project delivery methods. Project delivery methods are no longer seen only as procedures to follow for a construction project; they have become instruments that are being used to save money, deliver projects ahead of schedule and come up with innovative design solutions by utilizing the contractor's expertise.

This thesis evaluates the pros and cons of project delivery methods with respect to trenchless construction. Trenchless technology methods not only provide solutions that are less disruptive to the social and ecological environment but also solutions that significantly reduce the life cycle cost of the project. With the choice of multiple project delivery systems available, this thesis evaluates each method for advantages and limitations that it brings to a trenchless construction project. The thesis also provides a Decision Support System (DSS) to aid in the selection of a specific project delivery method.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure Page

CHAPTER 1

INTRODUCTION

This chapter presents a brief introduction to trenchless technology methods and their requirements for specific project delivery methods used in general on construction projects and how the choice of a project delivery method would affect success or failure of the project.

Trenchless construction involves the installation, repair, renewal and replacement of pipelines with minimum surface and subsurface disruptions thereby improving safety, productivity and cost-effectiveness of pipeline installation and renewal (Najafi, 2005). The decision made in the selection of a project delivery method impacts all execution phases of the project. More specifically, suitability of a project delivery method greatly influences the efficiency with which the trenchless project is executed and thus constitutes a critical success factor for these projects. Such decisions should be facilitated by a thorough analysis of the project characteristics (Zhang, et al., 2009).

1.1 Background

Trenchless construction has come a long way from when it was introduced in the United States in the early 1980's. Trenchless technology provides solutions that are less disruptive to the social and ecological environment and significantly reduce the life cycle cost of the project. (Najafi, 2005).

With the choice of multiple project delivery systems available, this thesis studies each of the project delivery methods for advantages and limitations that it brings to each project. A survey of industry professionals, conducted as part of this research, helped to develop a decision matrix that will be useful in evaluating the type of project delivery system on a particular trenchless project.

The ultimate goal of this research is to prepare guidelines that will serve to guide professionals in their selection of a suitable project delivery method for trenchless construction projects.

1.2 Need Statement

The need of today's construction whether it be residential, commercial or infrastructure is to cut costs while maintaining schedule, quality, and scope. This realization has brought to light the importance of project delivery methods. Project delivery methods are no longer seen only as procedures to follow for a construction project – to take the project from the design and planning stage to the execution and finally to the commissioning of the project – they have become instruments that are being used to save money, deliver projects ahead of schedule and come up with innovative design solutions to address the challenges of specific projects.

Trenchless construction is a unique kind of construction simply because of a large number of unknowns, such as subsurface conditions, locating existing utilities, variability of ground and soil, pipe-soil-machine interactions, etc., involved in a given trenchless construction project. A majority of effort in a trenchless project goes towards planning for these unknown variables. It is for this reason that the choice of a suitable project delivery method gains even more importance in a trenchless project.

1.3 Objectives

The objectives of this thesis are:

(i) Evaluate the project delivery methods of Design-Bid-Build, Design-Build, Construction Manager at Risk, and Construction Manger as Agent to select the most optimum delivery method for a trenchless construction project.

(ii) Understand the general advantages and limitations that are inherent to each of the above mentioned project delivery methods.

(iii) Apply information gained from literature search, and industry survey to create a decision matrix for selecting a specific project delivery method.

1.4 Methodology

The methodology of this thesis is summarized below:

(i) Consult with industry experts for gathering information on common project delivery methods suitable for trenchless construction.

(ii) Analyze the various advantages and limitations of the above stated project delivery methods.

(iii) Conduct surveys of industry professionals to further gather data on the trenchless construction and project delivery systems.

(iv) Compile the data obtained from research and surveys to understand how the choice of the project delivery system affects the project.

(v) Create a decision matrix to represent the factors that should be taken into consideration while selecting the project delivery system.

1.5 Expected Outcome

The outcome of this research will determine suitability of different project delivery methods for trenchless construction. The four common project delivery methods will be examined against different project characteristics of project schedules, budgets, quality required, scope of project etc. A Decision Support System (DSS) prepared with this research will serve as a tool to gain perspective on the most appropriate project delivery method.

1.6 Thesis Organization

Chapter 1 presents introduction, need statement, methodology and expected outcome of this research. Chapter 2 provides a literature review on the project delivery methods that are commonly used in trenchless construction. Chapter 3 outlines a methodology behind this thesis in detail by giving a step by step narrative on the research performed. Chapter 4 outlines results of the research. Chapter 5 draws conclusions and offers recommendations for further study. References and appendices are provided at the end of this research.

1.7 Chapter Summary

While project delivery methods have been evaluated in the past for their suitability on conventional construction projects, there is a need to evaluate these project delivery methods for trenchless construction projects. The analysis of project delivery methods and creation of a relevant decision support system would be a valuable tool for the trenchless construction industry.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a literature review on the subject of evaluating project delivery methods for construction projects. It covers the research that has been conducted previously on creating Decision Support Systems for the selection of project delivery methods on construction projects.

2.1 Introduction to Project Delivery Methods

In project management, a delivery system is a contractual structure and a compensation arrangement that the owners use to acquire a completed facility that meets their needs (Mafakheri, et al., 2007). Project delivery methods acquire more importance on trenchless construction projects due to the variable nature of the projects. The most commonly used project delivery methods used on construction projects are (i) Design-Bid-Build (DBB) (ii) Design-Build (DB) (iii) Construction Manager at Risk (CMR) and (iv) Construction Manager as Agent (CMA) (Mahdi, et al., 2005). These methods are explained in the following sections along with the advantages that each of the methods offers on a project and considerations while selecting that particular project delivery method.

2.2 Design-Bid-Build (DBB)

In Design-Bid-Build, or the traditional project delivery method as it is most commonly known, the owner engages an engineer to prepare the design of the complete facility, including construction drawings, specifications and contract packages. The complete design package is then presented to contractors who bid for the work and possibly engage subcontractors to provide specialty construction of the project. The selected contractor is responsible for constructing the facility according to the design. With this project delivery system, the owner retains more control over the project with the individual selection of engineer and contractor.

This project delivery system has been the most widely used, and most well understood because of clearly defined roles for the parties involved. Figure 2.1 illustrates the relationship between the parties involved in the Design-Bid-Build process.

The Design-Bid-Build process consists of the following key steps:

1. Engineer prepares 100% design documents.
2. Owner or owner's representative obtains competitive bids based upon the 100% design documents.
3. Owner and/or owner's representative evaluates bids and awards construction contract to a contractor.
4. Contractor mobilizes orders materials and constructs project (Kramer, et. al., 2004).

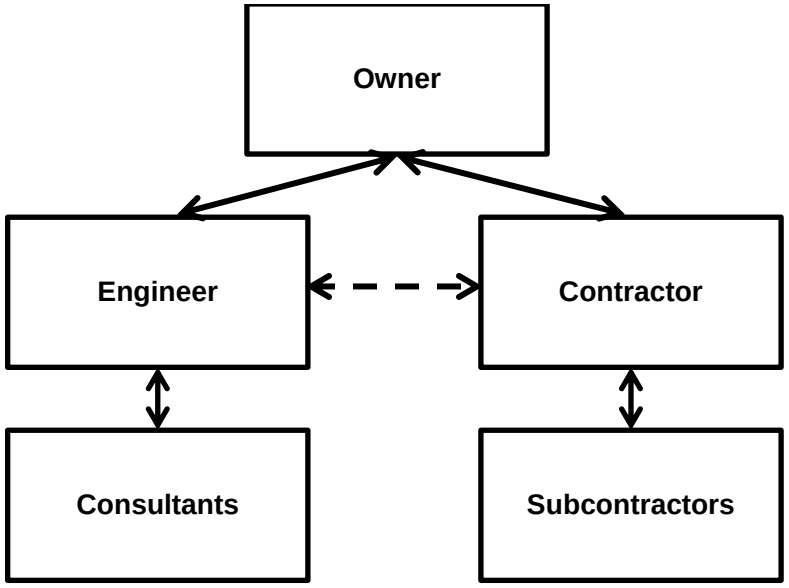

Figure 2.1 - Design-Bid-Build (DBB)

2.2.1 Advantages

The advantages of using the conventional method of Design-Bid-Build method include:

- The design and quality of construction are under the owner's control.
- Design changes can be easily accommodated prior to the start of the construction.
- Design is a 100% complete before the start of construction.

- Cost of construction is fixed when awarding the contract.
- Maximum competition leads to the lowest cost of construction.
- The roles of all parties involved in the project are clearly defined.
- There is relative ease of implementation.

2.2.2 Considerations

Factors to consider while selecting Design-Bid-Build as the project delivery method include:

- DBB requires significant owner expertise and resources.
- The responsibility of project delivery is shared.
- Owner is at risk to contractor for design errors.
- Design and construction are sequential, typically resulting in longer schedules.
- Construction cost is unknown until contract award.
- There is no contractor input in design, planning or value engineering.

2.3 Design-Build (DB)

The Design Build Institute of America (DBIA) defines Design-Build as a project delivery in which one entity - the design-build team - works under a single contract with the project owner to provide design and construction services (www.dbia.org). Owners interested in single-point responsibility for both design and construction can use the design-build delivery system. In the design-build, a consolidated entity provides both design and construction services to the owner and a single contract is established between the owner and the engineer-contractor or the design-build entity.

Design-build delivery requires an explicit determination of the roles and responsibilities of the design-build team, as single-source contracting has gained popularity in recent years in both the private and public sectors (Mahdi, et al., 2005). Figure 2.2 illustrates the relationship between the parties involved in the Design-Build process.

The Design-Build process consists of the following key steps:

1. Owner or Engineer prepares partial design documents. Design documents may range from as little as 10% to 50% complete or more.
2. Owner or owner's representative obtains qualifications and/or price proposals from contractors (possibly teamed with an engineering firm) based upon the partial design documents.
3. Owner and/or owner's representative evaluates qualifications and price proposals and selects contractor.
4. Design-Build team completes design and begins construction. Construction may begin prior to completion of 100% of the design (Kramer, et. al., 2004).

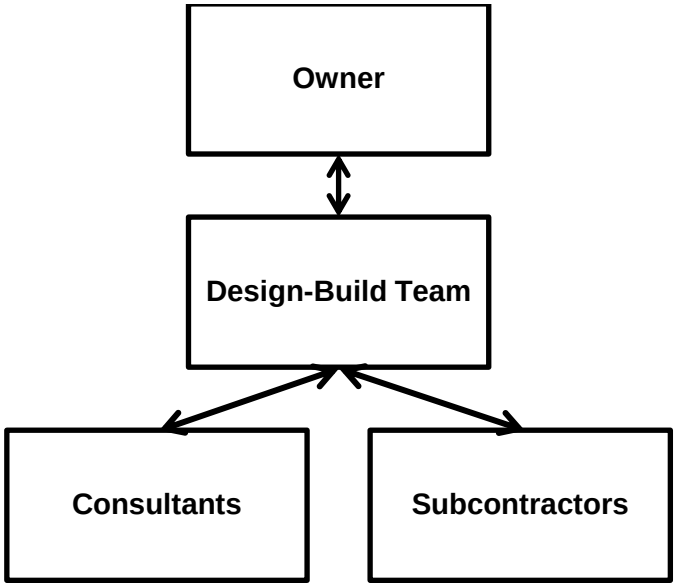

Figure 2.2 - Design-Build (DB)

2.3.1 Advantages

The advantages of using the project delivery method of Design-Build include:

- A single entity is responsible for design as well as construction.
- Construction often starts before design completion reducing project schedule.

- Construction cost is known and fixed during design assuring price certainty.
- The design and construction risk transfers from owner to the DB entity.
- There is emphasis on cost control.
- It requires less owner expertise and resources.

2.3.2 Considerations

Factors to consider while selecting Design-Build as the project delivery method include:

- There is minimal owner control of both design and construction quality.
- It requires a comprehensive and carefully prepared performance specification.
- Design changes after construction begins are costly.
- There are potentially conflicting interests as the same entity is both designer and contractor.
- There is no party responsible to represent owner's interests.
- Its use may be restricted by regulation.
- Since the bid costs are high, there are fewer bidders.

2.4 Construction Manager at Risk (CMR)

A construction manager-at-risk, or Guaranteed Maximum Price (GMP) contract, is intended to assume the risk for construction at the contracted price in the same manner as a general contractor; but also provides consultation to the owner regarding construction during and after the design of the facility. Construction management at-risk allows the client of a project to choose the CM before the design stage is complete. The CM company is chosen based on its qualifications, and then the entire operation is centralized under a single contract. The engineer and CM work together in order to cultivate and evaluate the design. Then, the CM gives the client a guaranteed maximum price, and coordinates all subcontract work. Usually, the owner keeps or shares the savings with CM, if the actual completed price of the project falls below GMP. Owner contracts engineer separately from the CM at-risk and the traditional client -

engineer relationship is maintained. Figure 2.3 represents the relationship between the parties involved in the Construction Manager at Risk process.

The Construction Manager at Risk process consists of the following key steps:

1. The owner contracts with the design consultant.
2. The designer prepares the preliminary design.
3. Owner evaluates and selects Construction Manager at Risk.
4. Owner contracts with CM for design phase services.
5. CM completes the design and bids for project components.
6. The GMP is negotiated and the construction phase contract begins.

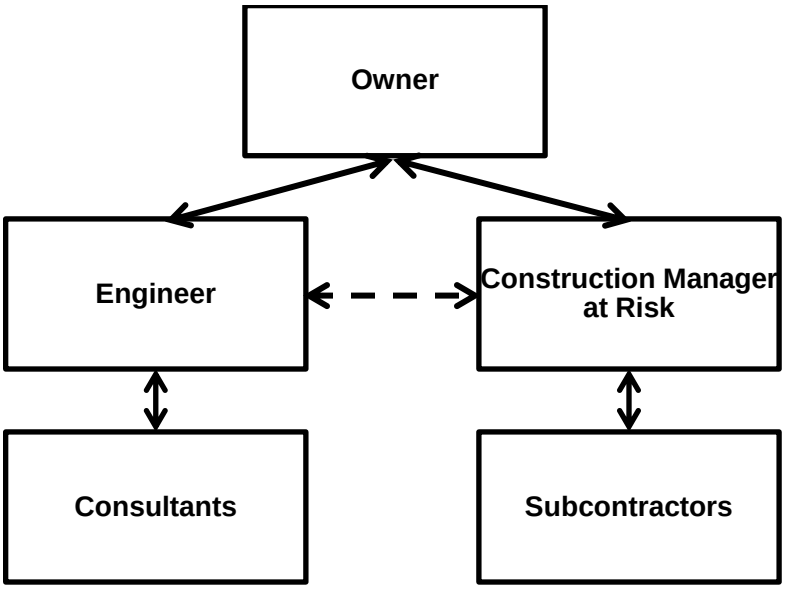

Figure 2.3 - Construction Manager at Risk (CMR)

2.4.1 Advantages

The advantages of using the project delivery method of Construction Manager at Risk include:

- The responsibility of construction and some risk transfers from the owner to CM.
- Construction cost is known and fixed during design.
- The CM has total control of construction and all subcontractors.

- The construction may start before design completion this reducing project schedule.

2.4.2 Considerations

Factors to consider while selecting Construction Manager at Risk as the project delivery method include:

- The owners control over construction is significantly reduced.
- Design changes after construction begins are costly.
- There can be potentially conflicting interests as both CM and contractor.

2.5 Construction Manager as Agent (CMA)

As the name implies, Construction Manager as Agent is merely an agent of the owner -- neither designing nor constructing the project. Instead, the Construction Manager administers the construction contract throughout the planning, design and construction phases of the project. As a general proposition, the Construction Manager as Agent is usually empowered to:

1. Act on behalf of the owner regarding contract matters, including overseeing the design and construction phases of the project; and
2. Transact specified business on behalf of the owner;

Under this model of construction management, the owner contracts separately with the Construction Manager, design professional and either a general contractor or (more frequently) several prime contractors. The Construction Manager has administrative relationships with the engineer and general contractor or prime contractors, but has contractual relationship only with the owner. The Construction Manager is generally not responsible for the means or methods of construction and does not guarantee construction costs, time or quality aspects of the work (Stein, et. al., 2010). Figure 2.4 represents the relationship between the parties involved in the Construction Manager as Agent process.

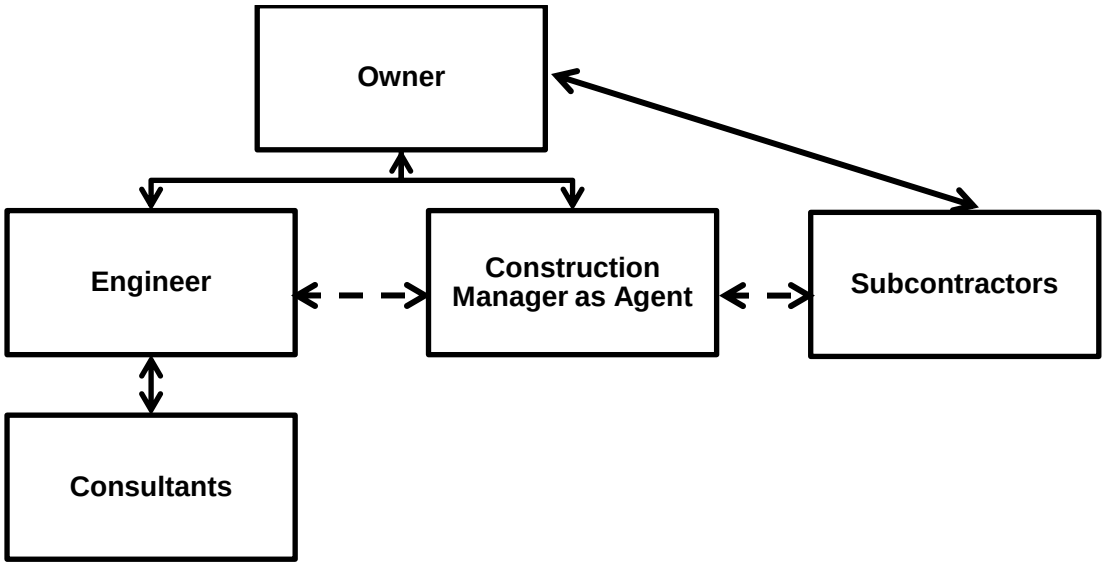

Figure 2.4 - Construction Manger as Agent (CMA)

2.5.1 Advantages

The advantages of using the project delivery method of Construction Manager as Agent include:

- Construction Manager as Agent is selected on qualifications rather than low bid.
- Early Construction Manager's involvement in estimating and constructability.
- Owner selects engineer, Construction Manager and subcontractors.
- Enables fast-track delivery (construction begins before design is complete thus saving time).

2.5.2 Considerations

Factors to consider while selecting Construction Manager as Agent as the project delivery method include:

- Construction Manager has no contractual responsibility with subcontractors.
- Final price is not established until all packages are bid.
- Guaranteed maximum price is not possible.
- Owner manages multiple contracts.

- Cost may be higher with multiple prime contractors.
- Higher owner administration costs to manage project.
- No single point of responsibility.

2.6 Decision Support Systems

Decision Support Systems (DSS) are a specific class of computerized information system that supports business and organizational decision-making activities. On construction projects, Decision Support Systems have been used for delay analysis (Yates, 1993). Decision Support Systems have also been used for developing on line systems that aid in making the most economic decisions on a construction project (Kaklauskas, et. al, 2007). A Construction Estimating Decision Support System (CEDSS) has been created for estimating the construction cost of single story homes.

The use of Decision Support Systems has been analyzed for various phases and types of construction projects. Decision Support Systems have been created for prequalification of web based tenders (Mohamad Noor, et. al, 2008). DSS has also been used on bridge construction (Hoshino et. al, 2000) and railway construction projects (Qin et. al, 2010).

Where trenchless construction and selection of project delivery methods is concerned, the application of a decision making process has been analyzed for the selection of the most appropriate trenchless technology on a project (Najafi, 2005) and the construction operations, planning, and estimating of trenchless construction projects has also been studied (Najafi, 2010). A Decision Support System has been developed for the selection of trenchless technologies to minimize the impact of utility construction on roadways (Gokhale, et. al, 2002). The use of a Decision Support System has been proven to be a valuable and valid instrument for making a choice of project delivery method on a construction project (Mahdi, et. al, 2004). The research for this thesis focuses on the development of a Decision Support System that assists in the selection of a project delivery method particularly for trenchless construction.

2.7 Chapter Summary

Of the various choices of project delivery methods available for construction projects, Design-Bid-Build (DBB), Design-Build (DB), Construction Manager at Risk (CMR), and Construction Manager as Agent (CMA) are most often used on trenchless construction projects. Each of the above mentioned methods brings their own unique advantages to the project while they also have drawbacks which need to be given careful consideration before selecting the project delivery method. While Decision Support Systems have been created for aiding with the choice of project delivery methods on construction projects, none of the Decision Support Systems have focused exclusively on trenchless construction projects.

CHAPTER 3

METHODOLOGY

This chapter discusses the research methodology for evaluating various project delivery methods for trenchless construction.

3.1 Introduction

The decision support system developed in this research is based on statistical weighted ranking. The survey was conducted by sending out a questionnaire to select trenchless construction industry experts. The survey helped in gathering information on project delivery methods being and served as a reality check for the results obtained from the Decision Support System.

3.2 Use of Surveys

Surveys are a research method involving the use of questionnaires and/or statistical surveys to gather data about people and their thoughts and behaviors. This method was pioneered in the 1930s and 1940s by sociologist Paul Lazarsfeld (www.encyclopedia.com/topic/Paul_F_Lazarsfeld.aspx). Surveys were used on this thesis for the research on suitable project delivery methods for trenchless construction projects. These surveys were sent out to professionals in the trenchless construction industry, who were asked to respond to the survey based on their experience in dealing with trenchless construction projects. It was ensured that the survey participants belonged to various sections of the trenchless industry thus enabling the researcher to not only gain the perspective from the view of owners, contractors, and project managers but also engineers, designers, and equipment manufacturers.

3.2.1 Survey Questions

The survey asked relevant questions about current practices of using project delivery methods on trenchless construction. The participants were asked to respond to questions like the most frequently used project delivery method on trenchless construction and the project delivery method that they think offers the best value on a typical trenchless construction project.

The participants were also asked to specify the project characteristic that they believed was of the most important while selecting the project delivery method on a trenchless project. One of the most important questions on the survey asked the respondents to rank the appropriateness of the four project delivery methods of Design-Bid-Build, Design-Build, Construction Manager at Risk, and Construction Manger as Agent given certain scenarios faced on typical trenchless construction project.

3.2.2 Responses Collected

The survey was sent out through an online survey service called Survey Monkey (www.surveymonkey.com). This Website provides flexibility to design the survey and transmitting to a predefined list of survey participants. The online service also collects the responses which make it simple to analyze. Please refer to Appendix D for the survey questionnaire.

3.3 Creation of Decision Support System (DSS)

As mentioned in the previous chapters, one of the objectives of this thesis was to create a decision support system that would serve as a guidance tool for selecting the project delivery method on a given trenchless project. This Decision Support System can be used by project owners to select the project delivery method (PDM) based on the projects characteristics. Figure 3.1 illustrates how the score is calculated for each of the individual project delivery methods while Figure 3.2 represents the logic for output generation for the Decision Support System.

The Decision Support System asks the users questions distributed over 7 factor areas. These factor areas are as follows:

1. Project Characteristics
2. Owner Characteristics
3. Design Characteristics
4. Contractor Characteristics
5. Regulatory Characteristics
6. Risk Management
7. Claims & Disputes

The scope, budget, schedule, and quality of a project are defined through project characteristics. On a trenchless construction project, like any other construction project, the owner's requirements and demands are important; hence it becomes vital to take owner-defined characteristics into consideration. The owner should be willing to consider alternative project delivery methods based on costs savings and other project objectives required by the owner on the project. There might be restrictions on the use of alternative project delivery methods and this would be an important criterion while selecting this project delivery method on trenchless project. Some owners require that there be competitive bidding for the project and since this not possible with all the project delivery methods, there may not be a lot of options for the selection of a specific project delivery method.

Since many trenchless technology methods are still developing with new innovations, it is important that the contractor chosen for the project be familiar with the latest developments. The amount of risk involved on a trenchless project is relatively higher than a normal construction project simply because of the uncertainty involved in the project due to various factors such as soil conditions, layout of existing utilities, etc. The uncertainty also results in a higher potential for conflicts and disputes between the parties involved and hence these factors need to be considered while selecting a project delivery method.

3.3.1 Decision Support System

Figure 3.1 illustrates the calculation of scores of each Project Delivery Method while Figure 3.2 illustrates the ranking procedure for the Project Delivery Methods based on the calculated scores.

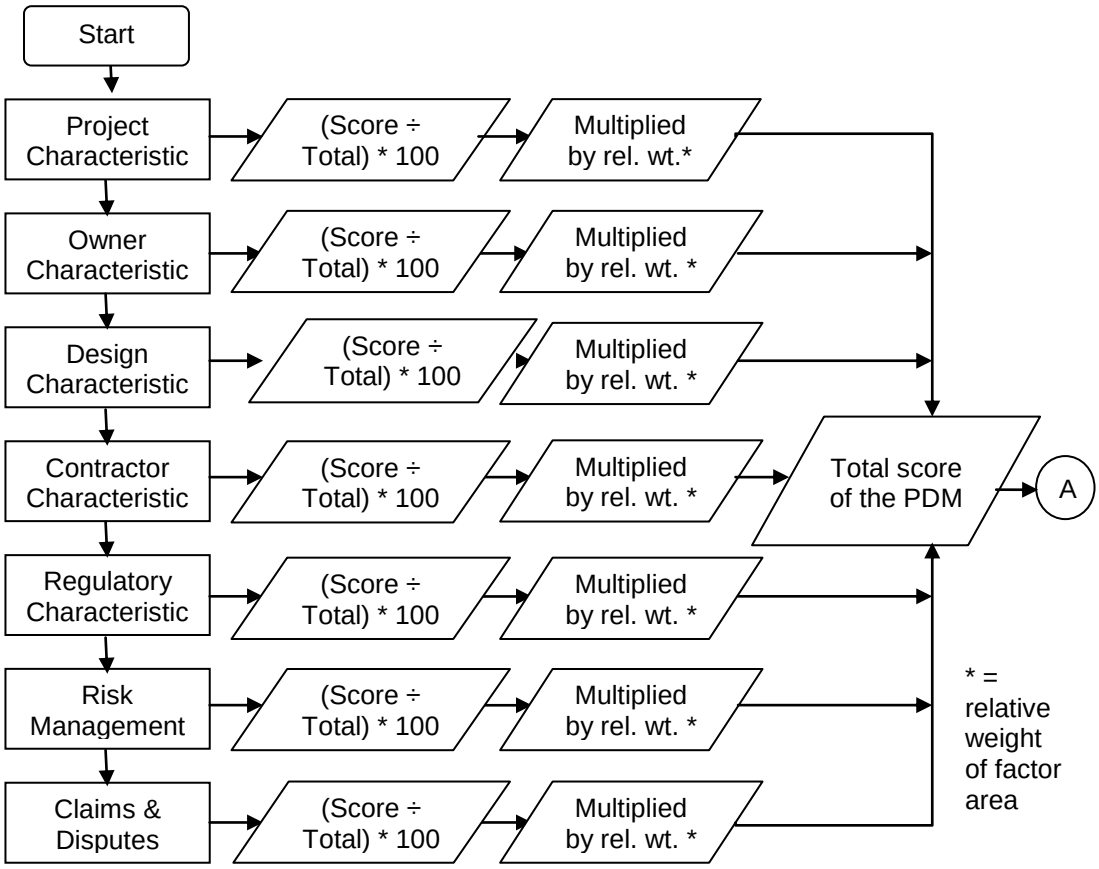

Figure 3.1 – Flow Chart for Scoring of Each Project Delivery Method on the DSS

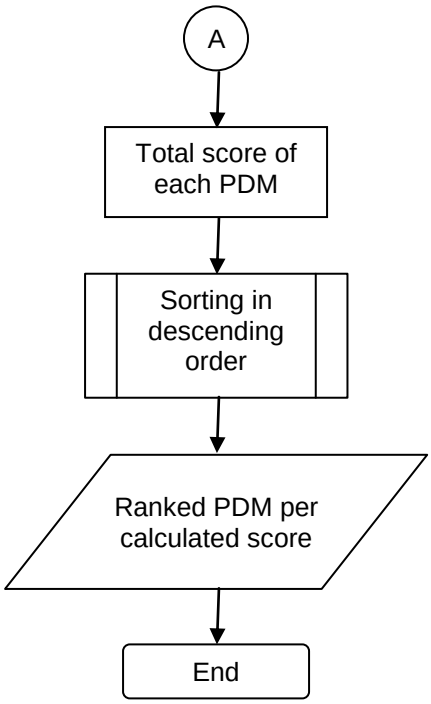

Figure 3.2 – Flow Chart for Output Generated by DSS

3.4 User Interface for DSS Model

In order to make the Decision Support System more accessible to the user, Microsoft Excel® is to create the user interface. The Excel worksheets allow the creation of an interactive user interface with the use of inbuilt formulas and functions.

As explained above, the user of the Decision Support System is asked a range of questions spread over various factor areas. The user is asked to respond to these questions with a ranking from 0 to 3, where the 0 means that the scenario stated in the question is not applicable to the project; 1 means that the probability of the scenario is not very likely to occur; 2 means the probability of the scenario occurring is in the medium range whereas 3 means that there is a high likelihood of the given scenario occurring in the project.

The score of each of the factor areas is then totaled and converted into a percentage so that it can be evaluated on a common basis. The factor areas are assigned relative weights based on a paper by Mahdi, et al. (2005), on creating a Decision Support System for selecting the proper project delivery method using analytical hierarchy process (AHP). The percentage

score for each factor area is then multiplied with the relative weight of that area ending up with a score for that project delivery method in that particular factor area. The score of each project delivery method is then totaled for all the factor areas. The final scores of the delivery method determine which method is most suitable for the project based on the input project characteristics.

Appendix C: User Manual for Decision Support System provides details on user interface functions.

3.5 Chapter Summary

A survey was used to create the decision support system which is one of the primary outcomes of this thesis. The survey helped to gain a perspective on the current practices being used in the trenchless construction industry. The Decision Support System was created after evaluating the survey results. The method of relative weights was used to rank the project delivery method from the most appropriate to the least appropriate method.

CHAPTER 4

RESEARCH RESULTS

This chapter presents the results of the research undertaken for this thesis. These results have been categorized into three areas, the results obtained from the survey and their analysis, the results obtained from the Decision Support System and the comparison of both of these results.

4.1 Analysis of Survey Results

4.1.1 Demographics

The respondents of the survey were spread out over 10 states in the United States as illustrated in Figure 4.1.

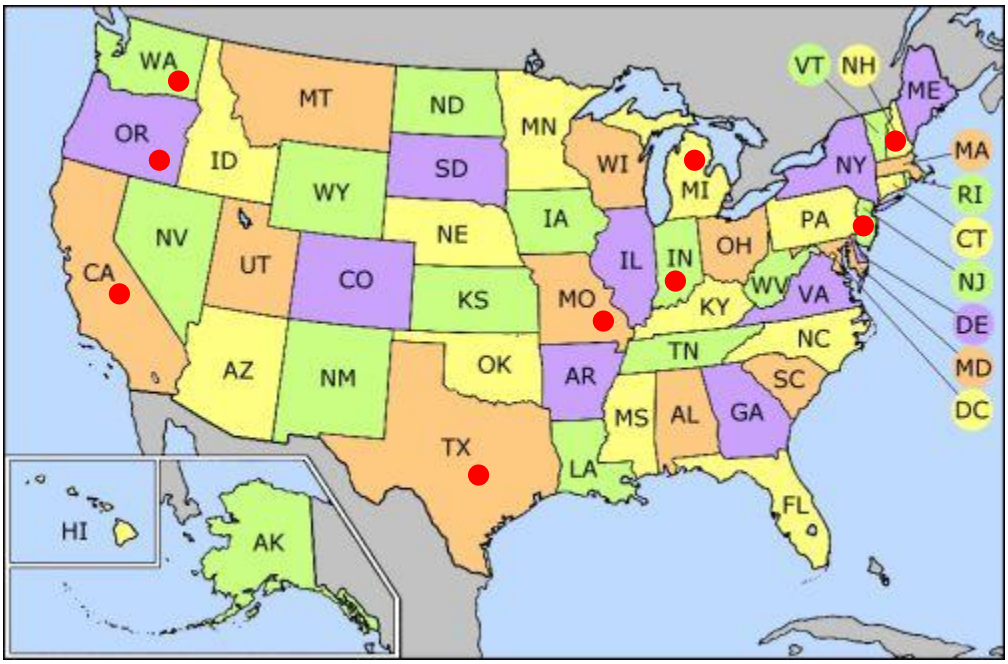

Figure 4.1 - Map of United States Depicting Areas of Survey Response

The respondents who answered the survey belonged to various areas of the trenchless construction industry. The distribution of the survey participants is represented by Figure 4.2.

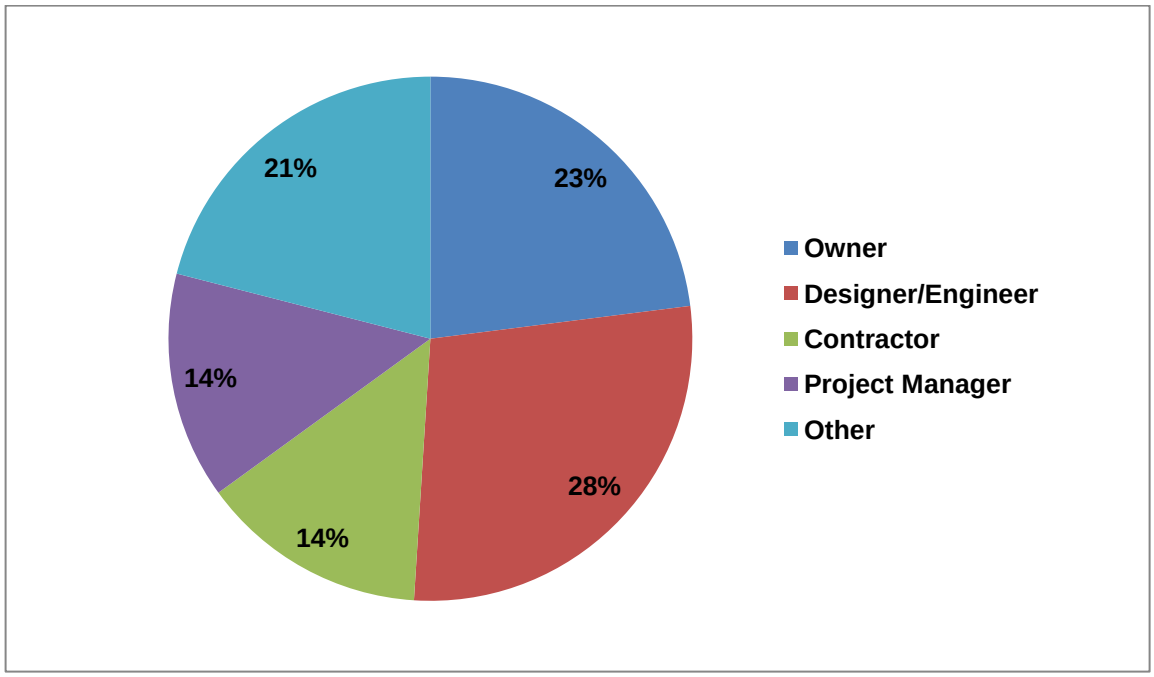

Figure 4.2 - Distribution of Survey Respondents by Position

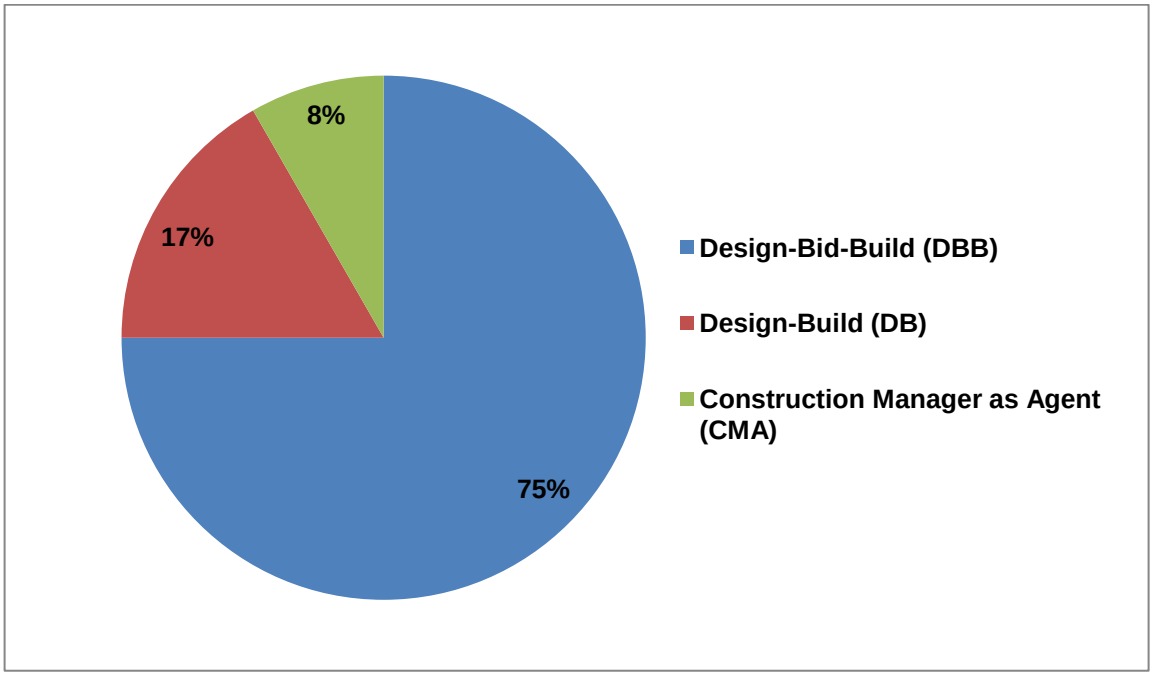

Figure 4.3 - Project Delivery Methods Most Frequently Used on Trenchless Construction Projects

The survey results (Figure 4.3) show that the most frequently used method on a trenchless construction project is Design-Bid-Build with Design-Build as a second choice for a trenchless construction projects.

4.1.2 Use of Project Delivery Methods on Trenchless Construction Projects

According to comments received by the survey participants, both Design-Bid-Build and Design-Build offer good value as project delivery methods on trenchless construction projects (Figure 4.4).

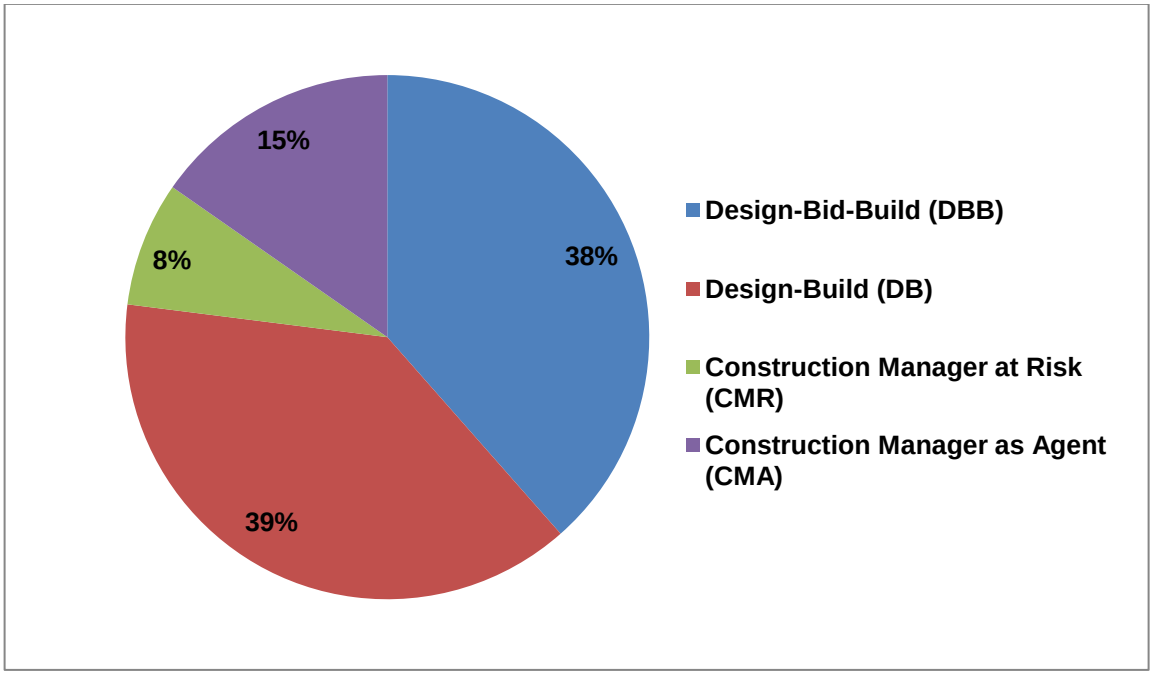

Figure 4.4 - Project Delivery Methods that Offer the Best Value on Trenchless Construction Projects

4.1.3 Influence of Project Characteristics on Choice of Project Delivery Methods

The survey demonstrated, as seen in Fig 4.5, that the characteristics that most affect the choice of a project delivery method are the cost and risk associated with the project. These are closely followed by the schedule and the quality of the project.

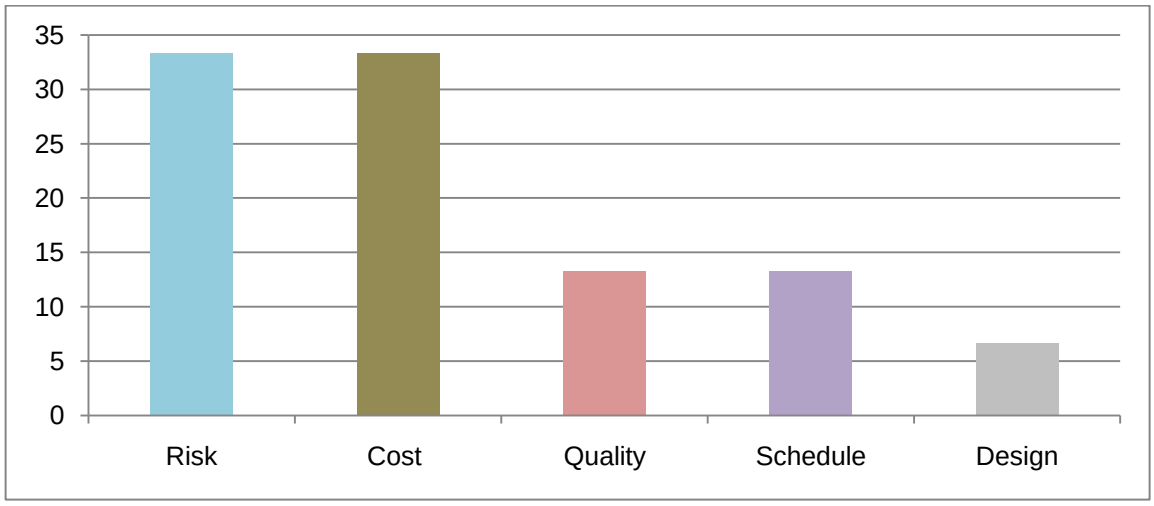

Figure 4.5 - Influence of Project Characteristic on Selection of Project Delivery Method

4.1.4 Impact of Project Delivery Methods

A majority of the survey participants agreed that the choice of project delivery method used on a trenchless construction project has a considerable impact on the success of the project. Figure 4.6 illustrates this data.

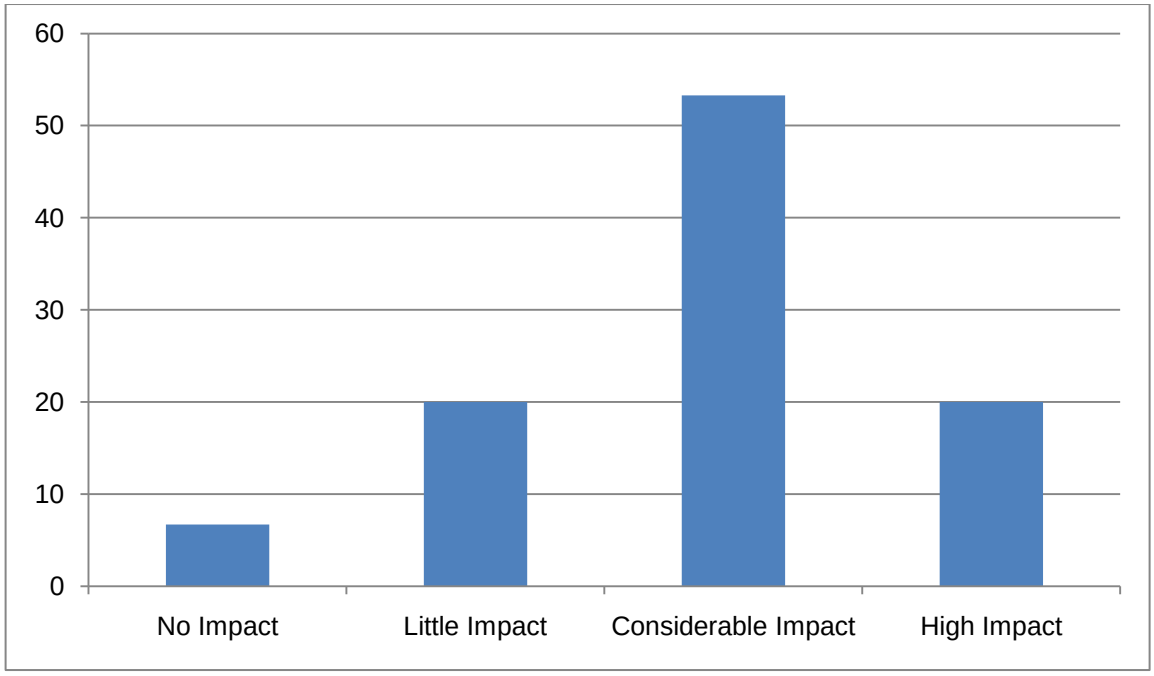

Figure 4.6 - Impact of Project Delivery Method on Project Success

4.1.5 Suitability of Project Delivery Methods

The survey participants were asked to rate the project delivery methods based on their suitability in certain scenarios that can be encountered on trenchless construction projects. The scenarios that were to be evaluated were:

1. Owner requires cost savings on the project
2. Owner has a high level of control over the design and project details
3. The project has tight deadlines
4. The size and scope of the project is complex
5. No flexibility to redesign the project once construction costs have been committed
6. There is a high potential for changes in design during construction
7. The quality of construction required is very high
8. The risk management plan on the project is minimal
9. Conflicts and disputes exist between the designer and the point of responsibility for the project (Figures 4.7 to Figures 4.10).

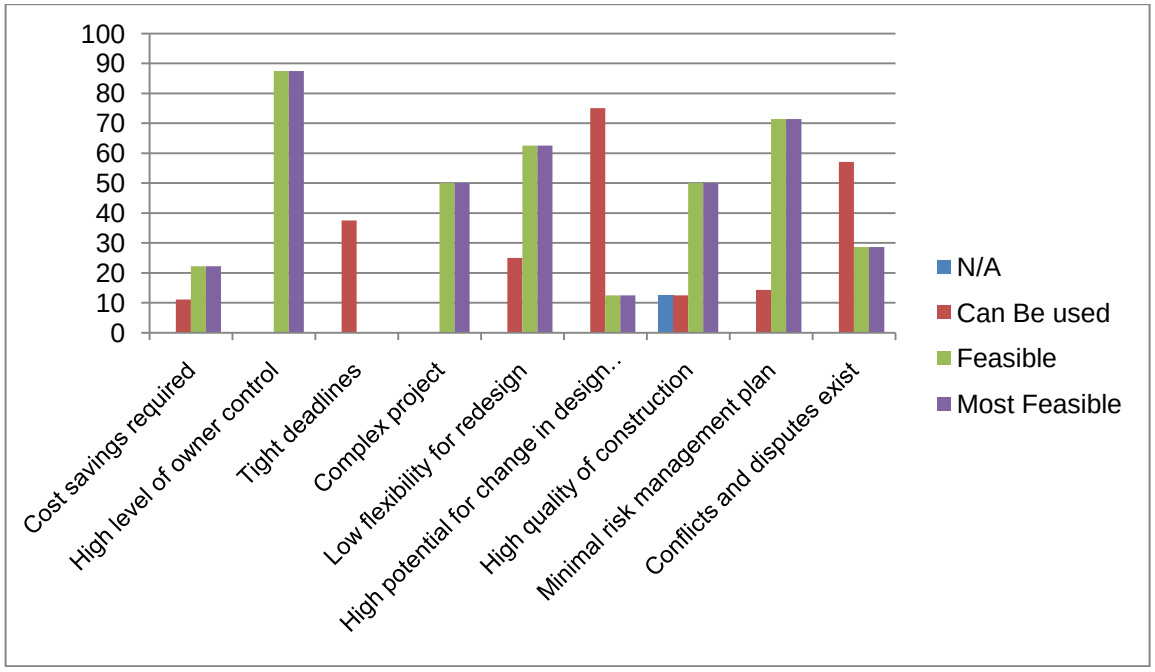

Figure 4.7 - Feasibility of the Design-Bid-Build (DBB) project delivery method

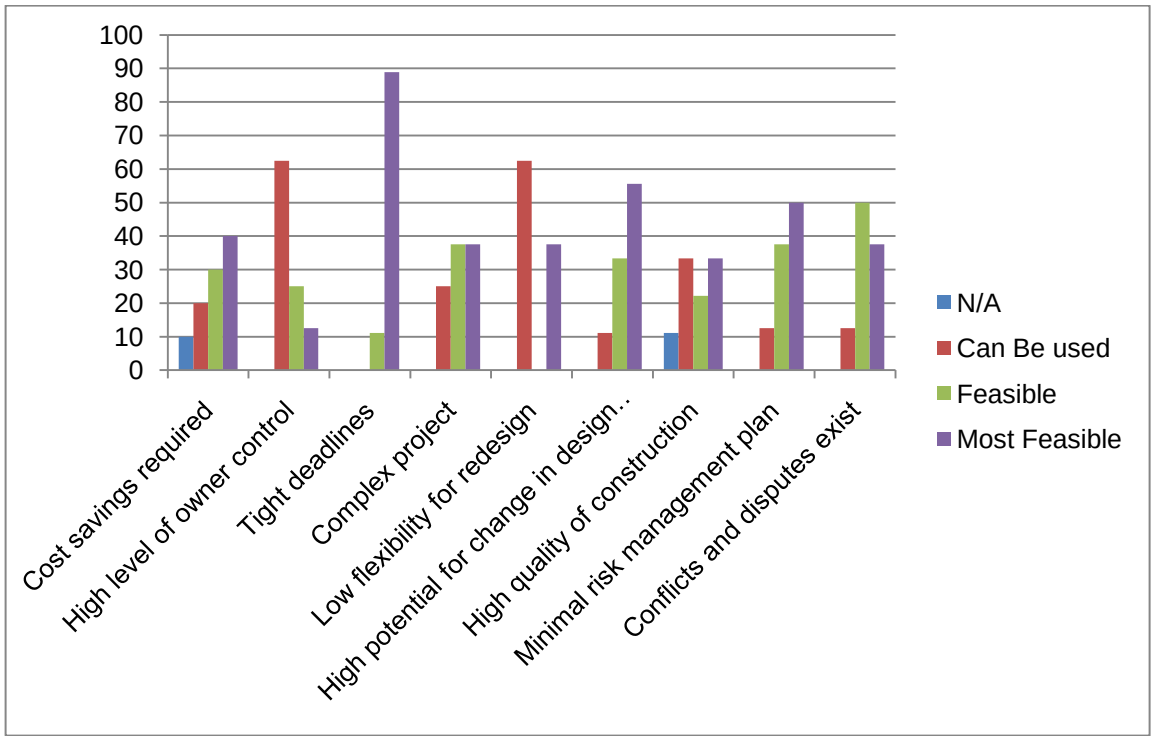

Figure 4.8 - Feasibility of the Design-Build (DB) Project Delivery Method

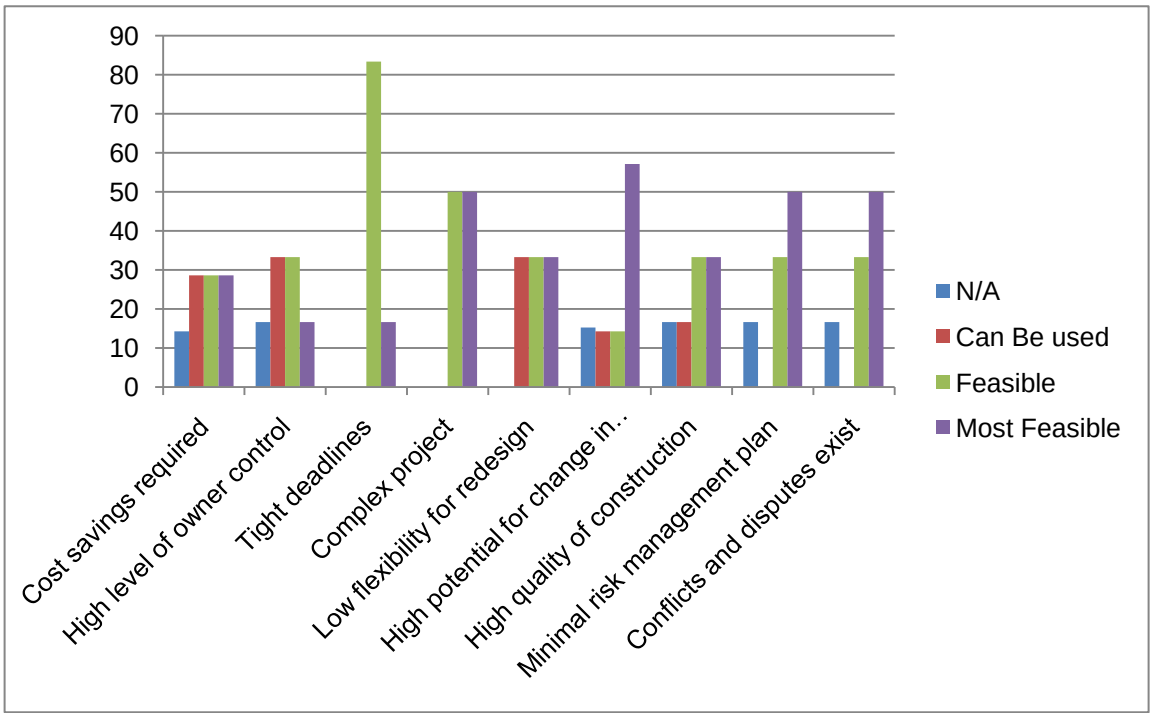

Figure 4.9 - Feasibility of Construction Manager at Risk (CMR) Project Delivery Method

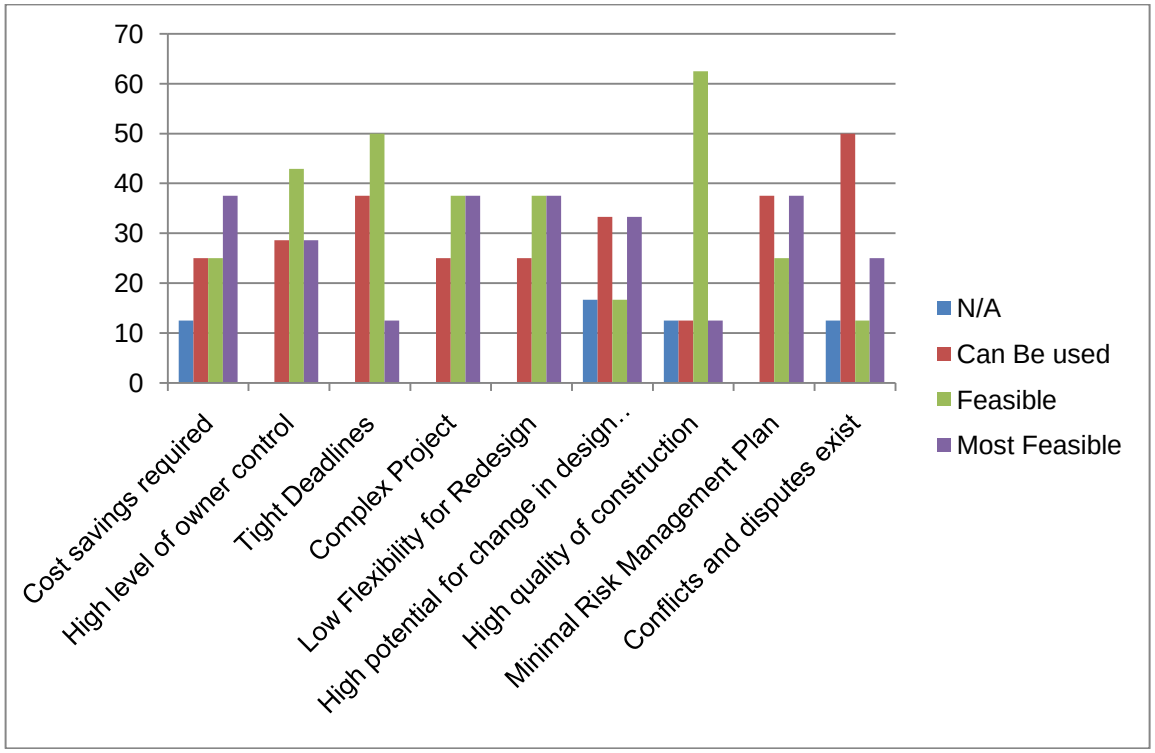

Figure 4.10 - Feasibility of Construction Manager as Agent (CMA) Project Delivery Method

Figures 4.7 through 4.10 illustrate that Design-Bid-Build (Figure 4.7) is most feasible as a project delivery method on trenchless construction when the project has a high level of owner control or does not have an adequate risk management plan in place. Design-Bid-Build can also be used as project delivery method when there is a high potential for changes in design during construction.

Design-Build (Figure 4.8) is most feasible when the project has tight milestones and deadlines to be met and when there is a high potential for changes in design during construction. Construction Manager at Risk (Fig 4.9) is most appropriate when dealing with a project that is complex in scope and nature. Construction Manager as Agent (Fig 4.10) can be used as a project delivery method when a high quality of construction is required.

4.1.6 Benefits of Project Delivery Methods

The survey respondents were asked for their opinion on the benefits provided by each of the project delivery method. They were asked to rate each of the project delivery method based on whether they thought that it was capable of providing a certain benefit on a trenchless construction project. The rating scale was 0 = Does not provide, 1 = may provide, and 2 = will definitely provide. The benefits that the participants were asked to evaluate the following benefits –

1. Making of timely decisions
2. Establishing a clear project definition
3. Communicating a clear scope of work
4. Providing leadership for project collaboration
5. Communicating clear business goals to design and construction teams
6. Dealing with change orders (Figures 4.11 to Figures 4.14)

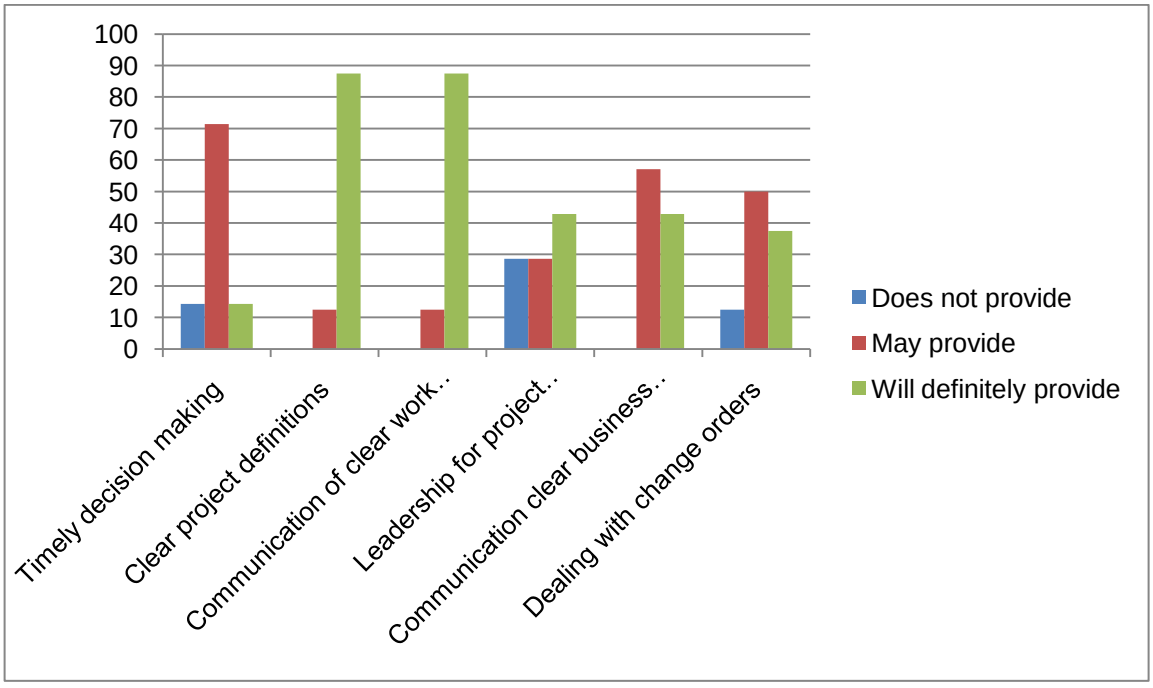

Figure 4.11 - Benefits Provided by Design-Bid-Build (DBB) Project Delivery Method

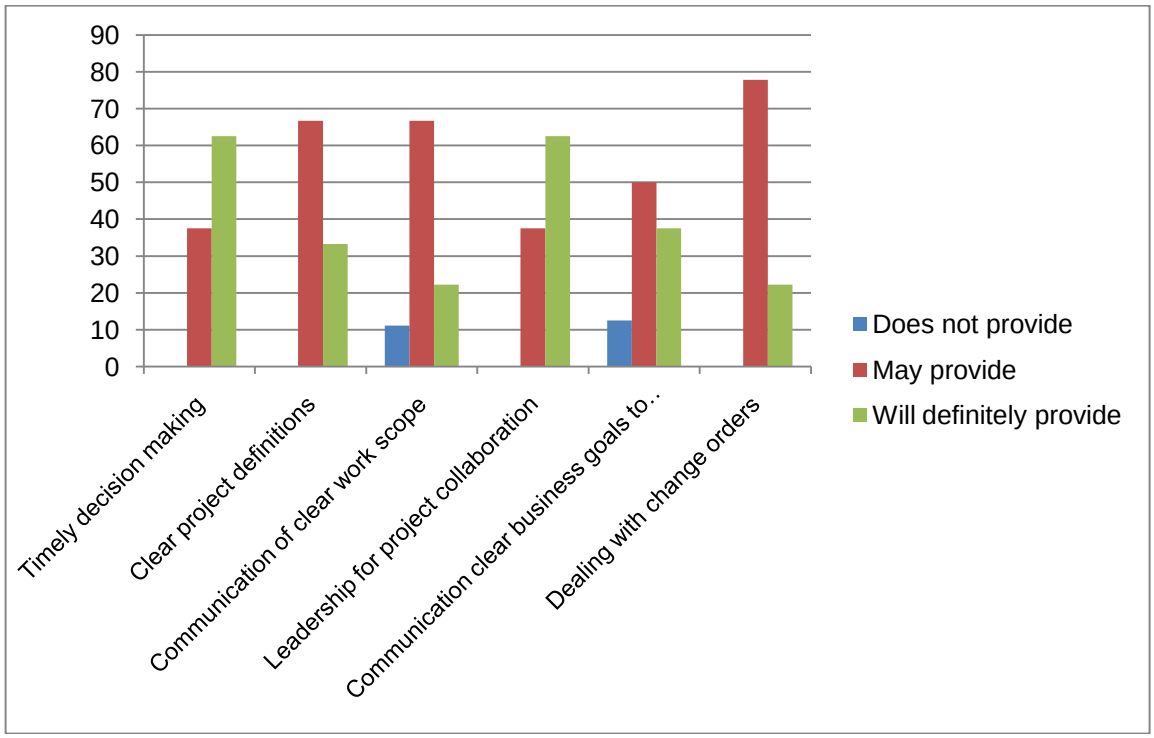

Figure 4.12 - Benefits Provided by Design-Build (DB) Project Delivery Method

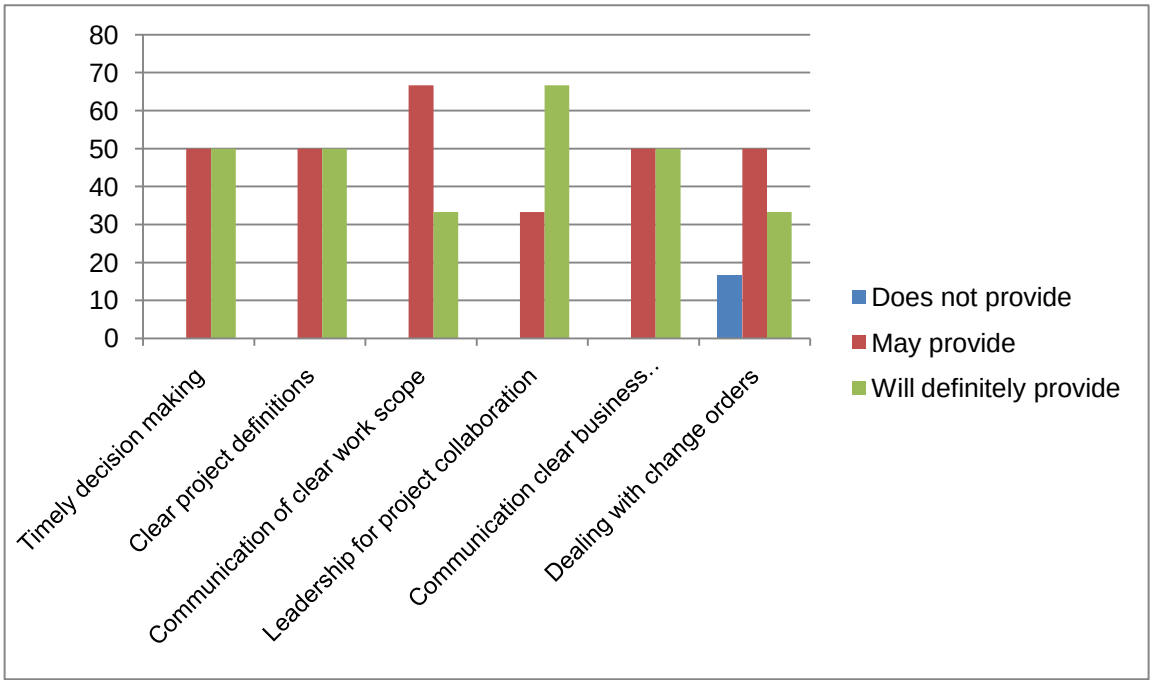

Figure 4.13 - Benefits Provided by Construction Manager at Risk (CMR) Project Delivery Method

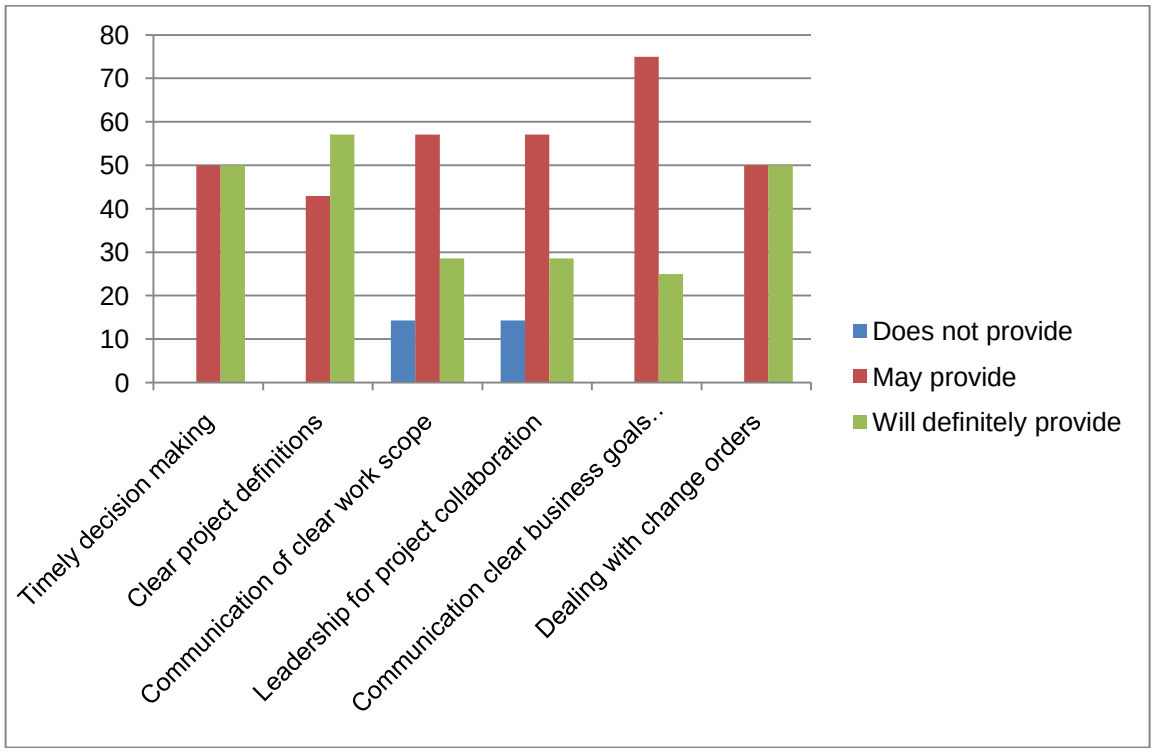

Figure 4.14 - Benefits Provided by Construction Manager as Agent (CMA) Project Delivery Method

Figures 4.11 through 4.14 illustrate that Design-Bid-Build can offer the advantages of providing a clear project definition and also of communicating clear scope of work to all parties involved. The project delivery method of Design-Build offers the advantages of enabling timely decision making and provides leadership for successful project collaboration.

Construction Manager at risk offers clear communication of project goals to the design and construction teams and also establishes clear project definitions. Construction Manager as agent is also beneficial for making timely decisions and dealing with change orders.

4.2 Comparison of Results

The industry survey described above, not only helped in gaining an insight into the way the trenchless construction industry currently works, but also provided the basis for a reality check for the Decision Support System, thus ensuring that the Decision Support System was based on a sound logic.

The results from the survey can be compared with the results from the Decision Support System by inputting the same constraints into the Decision Support System as were evaluated by the survey participants.

For the first constraint, if the owner would like a high level of control over the project details, the project characteristics are assigned a medium probability of occurring. The results given by the decision support system are illustrated in Figure 4.15.

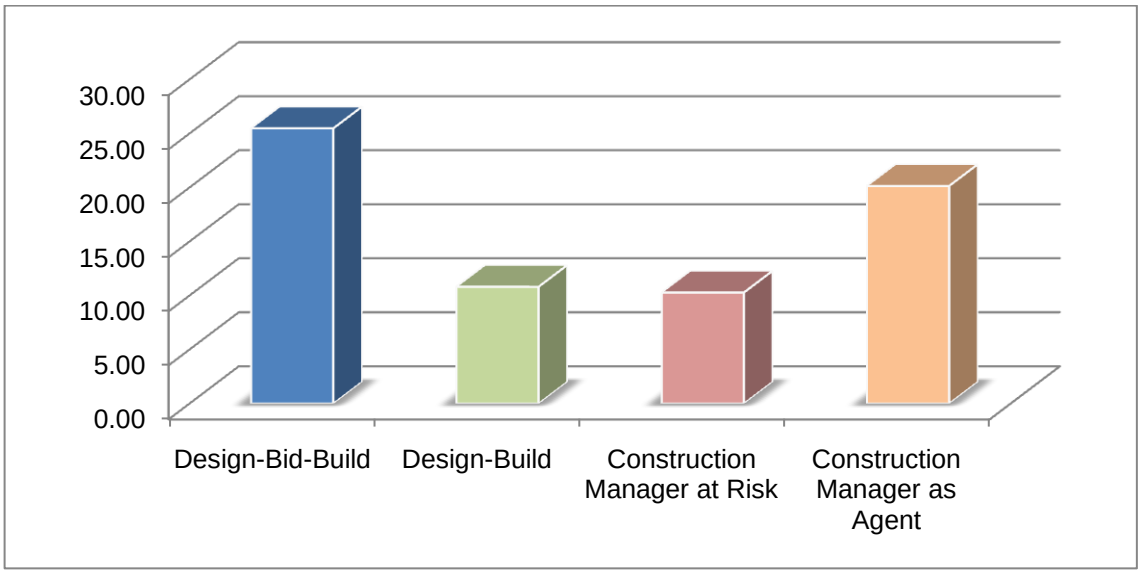

Figure 4.15 - Output of DSS in the Scenario of a High Level of Owner Control

The DSS results as illustrated in Figure 4.15 correspond with the survey results which indicate that the top methods preferred by trenchless construction industry in case of a high level of control of the owner are Design-Bid-Build and Construction Manager as Agent.

Similarly, with another constraint of tight project deadlines, the output given by the Decision Support System is illustrated in Figure 4.16.

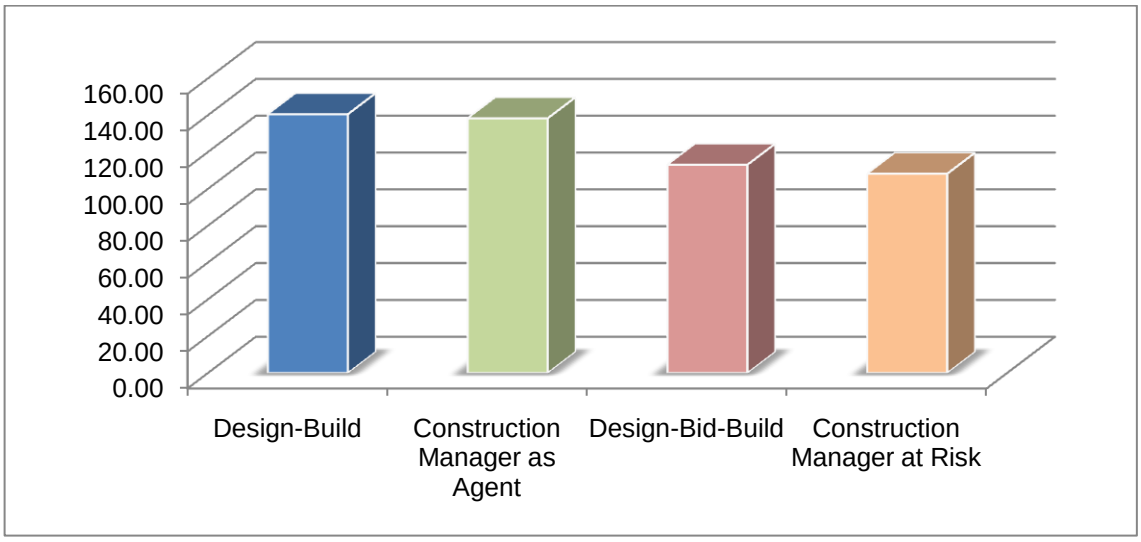

Figure 4.16 - Output of DSS in the Scenario of Tight Deadlines on a Project

As can be seen from Figure 4.16, Design-Build is offered the most viable project delivery method, in the case of tight deadlines on a project. This result can again be compared to that received from the survey participants, which indicated that in the case of a project having tight deadlines the preferred method of project delivery is Design-Build.

To offer another example of the logic of the Decision Support System, we can look into the scenario of a high quality of construction being required on the project: Figure 4.17.

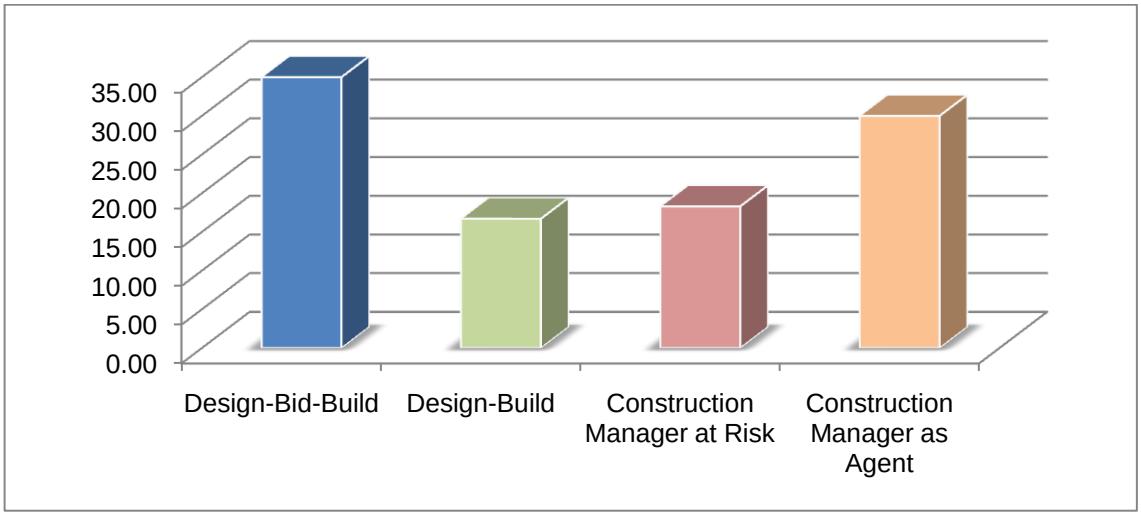

Figure 4.17 - Output of the DSS in the Scenario of High Quality Required on the Construction Project

Once more, as illustrated in Figure 4.17, the results given out by the DSS are substantiated by the results obtained from the survey. It is clear that if a high quality of construction is required, the most feasible project delivery method would be the Design-Bid-Build or Construction Manager as Agent.

4.3 Chapter Summary

A survey was sent out to professionals in the trenchless construction industry. The survey participants belonged to various areas of the trenchless construction including engineers, project managers, contractors, and owners. The survey shows that the most frequently used project delivery method on trenchless construction projects is Design-Bid-Build but that the industry is slowly turning to Design-Build as a better alternative for trenchless construction. The survey participants also responded that the choice of the project delivery method had a considerable impact on the success of a trenchless construction project. They provided their opinion on the benefits offered by each of the project delivery method along with the feasibility of each of the project delivery methods based on several project parameters.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter includes the conclusions drawn from the research conducted on evaluating project delivery methods for trenchless construction. It also includes the recommendations for future research for the same subject area.

5.1 Conclusions

The following conclusions can be derived from this thesis:

- The project delivery method that is most frequently used on trenchless construction projects is Design-Bid-Build. The reason for this may be two fold. Trenchless technology in itself is relatively new and the industry may be hesitant in experimenting with alternative project delivery methods on trenchless construction. Also, Design-Bid-Build is a method with which most contractors are familiar and thus the ease of implementation of this project delivery method is high.
- Design-Bid-Build serves best on a project if cost savings are required on a project or if the risk management plan on a project is minimal.
- Design-Bid-Build provides a clear project definition and a good communication of the work scope to all parties involved.
- The trenchless construction industry is slowly beginning to turn towards Design-Build as a project delivery as it realizes the value that this alternative project delivery method offers on trenchless construction projects.
- The Design-Build method of project delivery is most suited to projects with tight deadlines.
- Design-Build offers the benefits of timely decision making and establishment of a single source for successful project collaboration.

- Construction Manager at Risk is most suited to projects which are complex in scope and nature and also when there is a high potential for changes in design during construction.
- Construction Manager at Risk offers clear communication of project goals to the design/construction team. Owners can benefit from possible savings in the project.
- Construction Manager as Agent is a viable project delivery on projects that require a high quality of construction.
- Construction Manager as Agent offers best value on a project when a clear project definition is needed and there is a high likelihood of addressing multiple change orders.
- The choice of project delivery method used on a trenchless construction project is governed by the cost and the risk as well as quality and schedule associated with the project.
- Experts in the trenchless construction believe that the choice of project delivery method on a trenchless construction project considerably affects the success of that project.

5.2 Recommendations for Future Study

The following topics are recommended for future research on the subject of selecting the most optimized method of project delivery for trenchless construction.

- The study can be further expanded to include more alternative project delivery methods such as engineering-procurement-management, time and material, and others, to offer a wider choice to the user selecting a specific project delivery method.
- The survey for the basis of the decision support system can be conducted on a wider scale.

- The survey and the DSS can be narrowed to specific trenchless method, such as microtunneling, HDD[1], CIPP[2] (Najafi, 2010), etc., as well as size and complexity of the project.
- The user interface for the Decision Support System should be created on a more user friendly graphical interface such as visual basic.
- The survey results should be evaluated for skewness based on the position of the survey respondent within the trenchless construction industry.

[1] Horizontal Directional Drilling
[2] Cured-in-place Pipe

APPENDIX A

SURVEY QUESTIONNAIRE

UNIVERSITY OF TEXAS ARLINGTON

Hello,

This voluntary questionnaire is part of a study being conducted on 'Project Delivery Methods for Trenchless Construction'. The purpose of this study is to correlate the characteristics of a trenchless construction project with the project delivery method to be used on the project. The questions are designed to help us understand the link between project characteristics and project delivery methods so that hopefully the selection of project delivery methods for trenchless construction projects can be optimized. Identifying what you think about project delivery methods for trenchless construction will be instrumental in order to reach that goal.

Your very valuable input will help us to create a decision support system to assist with the selection of project delivery methods on trenchless construction because only you can supply the required information. This study is being conducted by Sahar Hasan (contact information provided below) under direction from Dr. Mohammad Najafi, P.E. Professor at the University of Texas at Arlington (contact information provided below). A copy of the Survey Results can be sent to you by e-mail at your request.

The questionnaire asks you for information on your experience with project delivery methods on trenchless construction. The survey contains 9 questions, and we estimate it will take an average of 10 minutes to complete the survey. Your completion of this survey is voluntary. You are free to not answer any question or to stop participating at any time. As this is an electronic survey, we do not track or record the IP address from which you are responding. There are no risks or individual benefits (accept receiving a copy of the research findings as noted above) associated with taking this survey. The responses collected will be kept confidential by the researcher to the maximum extent allowable by law. By completing this survey, you indicate your voluntary consent to participate in this study and have your own answers included in the project data set.

Thank you in advance for your help, we do appreciate your time.

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Your Contact Information

Name:	
Company:	
Address:	
City/Town:	
State:	
ZIP:	
Country:	
Email Address:	
Phone Number:	

Please indicate your position within the industry. (Please check all that apply)

- ☐ Owner
- ☐ Designer/Engineer
- ☐ Contractor
- ☐ Subcontractor
- ☐ Project Manager

Other (please specify) _____

Which project delivery method is most frequently used on trenchless construction projects?

- ○ Design-Bid-Build
- ○ Design Build
- ○ Construction Manager at Risk
- ○ Construction Manager as Agent

Other (please specify) _____

Which project delivery method do you believe offers the best value on a trenchless construction project?

- ○ Design-Bid-Build
- ○ Design-Build
- ○ Construction Manager at Risk
- ○ Construction Manager as Agent

Other (please specify) _____

Which of the following factor, do you believe, would most influence the choice of the project delivery method to be used on a trenchless construction project?

- ○ Cost
- ○ Schedule
- ○ Design
- ○ Quality
- ○ Risk

Other (please specify) _____

Please indicate the impact of the choice of project delivery method on the overall success of a trenchless construction project.

- ◉ No impact
- ○ Very little impact
- ○ Considerable impact
- ○ High impact

Please indicate the most feasible project delivery method for a trenchless construction project, in case of the following scenarios.
(0 = Not applicable in given scenario; 1 = Could be used with some difficulty; 2 = Feasible; 3 = Most feasible)

	Design-Bid-Build	Design-Build	Construction Manager at Risk	Construction Manager as Agent	Other (Please specify in the comment field below)
Owner requires cost savings on the project					
Owner has a high level of					

	Design-Bid-Build	Design-Build	Construction Manager at Risk	Construction Manager as Agent	Other (Please specify in the comment field below)
control over the design and project details					
The project has tight deadlines					
The size and scope of the project is complex					
There is no flexibility to redesign the project once construction costs have been committed					
There is a high potential for changes in design during construction					
The quality of construction required is very high					
The risk management plan on the project is minimal					
Conflicts and disputes exist between the designer and the point of responsibility for the project					

Other (please specify)

Please indicate which of the project delivery method provide the following advantages on a trenchless construction project. (0 = does not provide; 1 = may provide; 2 = will definitely provide)

	Design-Bid-Build	Design-Build	Construction Manager at Risk	Construction Manager as Agent	Other (Please specify in the comment field below)
Making of timely decisions					
Establishing a clear project definition					
Communicating of a clear work scope					
Providing of leadership for project collaboration					
Communicating of clear business goal to design and construction teams					
Dealing with change orders					

Other (please specify)

APPENDIX B

USER MANUAL FOR DECISION SUPPORT SYSTEM

Getting Started

The Decision Support System opens with a start page with a link to get started with the Decision Support System. The system is based on a very simple rating method. The following pages of the decision support system put forward a range of scenarios over several factor areas.

Using the Decision Support System

The user has to rate the given scenarios based on the probability of the scenarios based on the likelihood of these scenarios occurring on a particular trenchless construction project. The rating varies from 0 to 3 where –

0 = Scenario is not applicable to the given project

1 = Scenario has a low probability of occurring on the given project

2 = Scenario has a medium probability of occurring on the given project

3 = Scenario has a high probability of occurring on the given project

Navigating the Decision Support System

- The Decision Support System can be started by clicking on the start link on the first page.
- The start link takes the user to the first set of questions about project characteristics.
- Once the user has completed one set of questions they can move forward to the next by using the link provided at the bottom of the page.
- The Decision support system then takes the user through questions on Project Characteristics, Owner Characteristics, Design Characteristics, Contractor Characteristics, Regulatory Characteristics, Risk Management, and Claims and Disputes on the project. The definitions for each of the scenarios on the Decision Support System are included in this user manual.
- The last set of questions pertains to claims and disputes existing on the project, once the user has completed this set of questions, they can click on the link for the Output.

- The output page provides the ranking of project delivery method based on the input by the user. It also provides a link to the calculation sheet so that the user can view the steps through which the ranking of the project delivery methods has been assigned.
- The output page also provides links to the graphs of the project delivery method as per individual project characteristics. The user can return to the output page by using the link provided on each of these pages.
- The user can also start over by using the link provided on the output page.

Definitions

Tight project milestone or deadlines: by determining if the project requires a schedule that can only be maintained by overlapping of the design and construction phases to consider one alternative delivery options. If the project has a fixed schedule or finish date before it is submitted to its executor.

Cost saving: identifying the possibility of cost saving for each alternative delivery option.

Precise cost estimate before contract signing: the owner's need for a more precise cost estimate before contract signing in case there is a limited budget.

Project budget: the project has a fixed cost before it is submitted to the designer.

Ability to define the project scope: the owner has a precise understanding of the project scope before it is submitted to the designer.

Project size and complexity: the size and monetary amount of a project as compared to others available for the designer and contractors - If the project uses unique or specialized building techniques, if the owner has the ability to define the project scope, if the owner can manage the project with either in house staff or with a pre-construction consultant.

Applicability: the possibility of applying the different delivery options by the owner.

Owner control over design: ability or desire to take responsibility for managing the design. Does the owner have in-house design resources qualified to manage the design professional.

Owner understanding the project scope: the owner, designer and contractor share a clear understanding of functional and technical performance required in the finished project.

Owner benefits from cost saving: is the owner getting a benefit from cost saving.

Owner involvement in project details: does the owner wish to have complete involvement in the project details?

Design quality: is it available in house or does the owner need outside resources to verify the design quality.

Potential for design changes during construction: is there is a significant potential for changes during the construction phase.

Flexibility to redesign after construction cost commitment: is a significant amount of flexibility required after commitment to a contractor.

Contractor input in design: is contractor input during design required or desired to assist in defining scope, constructability reviews, schedule determination or budget confirmation.

Expertise required: experience with the particular delivery method – If it is available by the owner in-house personal or by other agency.

Risk allocation and risk management improvement: the owner prefers to shift some of the traditional risks (e.g., design errors and omissions) to the design builder.

Regulatory and statutory requirements: do laws rules, regulations, etc., permit the use of an alternative project delivery method?

Availability of experience required to carry out the delivery option: the number of local designers, contractors, and design-build firms with appropriate experience.

Claims and disputes between design and builder/single point responsibility: does the owner desire to hold a single entity responsible for coordination, collaboration and productivity for the entire project?

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BIOGRAPHICAL INFORMATION

At the time of presentation of this paper, Sahar Wasim Hasan has a Bachelors Degree in Civil Engineering from the University of Mumbai. She has continued to maintain a strong academic standing while pursuing a Masters in the area of Construction Management and Engineering at the University of Texas at Arlington. Ms. Hasan has been under employment of the University of Texas at Arlington as a Graduate Teaching Assistant for the semesters of Fall 2009 and Summer 2010. She has been the recipient of the Civil Engineering Department Graduate Scholarship for Spring 2009 semester and Center for Underground Infrastructure Research and Education (CUIRE) for Fall 2010 semester. Ms. Hasan has served as Treasurer on the UT Arlington student chapter of the North American Society of Trenchless Technology and has been an active student member of ASCE. She is the recipient of the Michael E. Argent Memorial Scholarship by NASTT for 2010.