A Decision Support System for Project Delivery Method Selection in the Transit Industry

A Dissertation Presented

by

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Dedication

This dissertation is dedicated to my parents, Abdolkarim and Fereshteh, in recognition of their support and love.
Abstract

The US government annually spends billions of dollars on transit projects. State transit agencies as the owners of these projects hire designers, construction contractors, vendors, and consultants to execute the project. An appropriate project delivery method can assist them in achieving the project goals. A project delivery method (PDM) is a framework of all project stakeholders’ legal relationships and responsibilities. The delivery method selection should be based on a systematic approach that includes all available PDMs and all of the project’s qualitative and quantitative characteristics that may be influenced by the delivery method option. This dissertation provides a comprehensive solution for this common challenge in the transit industry. The decision support system (DSS) developed in this research provides useful information and introduces the advantages and limitations of each PDM to the decision makers. A requisite well-structured decision making process is embedded in the proposed framework of this decision aid tool that is reliable and sufficient to solve the problem of selecting an appropriate PDM.

The dissertation covers all the available PDMs (i.e. Design-Bid-Build (DBB), Design-Build (DB), Construction Management at Risk (CMR), and Public-Private Partnership (PPP)). A comprehensive set of critical issues are defined in this dissertation and advantages/disadvantages of each delivery method is thoroughly studied with respect to these issues. Multi-attribute decision tools are also applied as another approach to select a PDM. Using quantitative risk analysis and concentrating on the effects of PDM option on the project risks is studied in this research effort.
Highlighting the financial aspects of PDM selection is another core element of this dissertation in which some concepts such as Value for Money and Public Sector Comparator are explained and incorporated. The details of Net Present Value (NPV) calculation for PPP and conventional methods and its implementation to a hypothetical project are presented in this dissertation. Several interviews and case studies were conducted to collect relevant information on the state of practice in the US transit industry and validate the developed system at the end.
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A successful academic path with several invaluable accomplishments would not have happened without God’s blessings. I am thankful to him for his kindness, provisions, and protection. I owe my deepest gratitude to my parents Abdolkarim and Fereshteh who have supported me throughout my life and have always remembered me in their prayers. This dissertation is dedicated to them to show my appreciation.

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Chapter 1. Introduction

Scope of the Research

This dissertation provides a solution for a common challenge faced by transit owners when they should select a project delivery method (PDM) for their projects. A PDM assists the owner in assessing its options in terms of project financing and delivery. To help the decision makers find the most appropriate PDM for their projects, an objective decision support system (DSS) is developed in this research. The DSS provides information and introduces the abilities of each PDM to the decision makers. A requisite well-structured decision making process is embedded in the proposed framework of this decision aid tool\(^1\) that is both reliable and sufficient to solve the challenge of selecting an appropriate PDM.

This dissertation proposes an objective decision support system in which transit agencies can select a PDM from Design-Bid-Build (DBB), Design-Build (DB), Construction Management at Risk (CMR), and Public-Private Partnership (PPP)\(^2\). The financial aspects of PDM selection is also described in the context of the DSS. This research includes the contributions of the author to a Transit Cooperative Research Program (TCRP) research project (TCRP 2009) and also provides new additions to those findings throughout the chapters. Accordingly, the research methodology introduced in this section reflects the

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\(^1\) “Decision aid tool” and “decision support system” are used interchangeably throughout this dissertation.

\(^2\) The DSS is partially based on a decision aid tool that was developed in two separate research efforts (TCRP G08 project “A guidebook for the evaluation of project delivery methods” and ACRP 01-05 “A guidebook for airport capital project delivery methods”).
way this research has evolved by first covering the methodology used for the TCRP Guidebook and then the following steps for the expansion of the DSS.

**Problem Identification**

The US government annually spends billions of dollars on new transit projects. State transit agencies as the owners of these projects have a set of goals and restrictions. An appropriate project delivery method can help them execute the project amid the challenges. “A project delivery method equates to a procurement approach and defines the relationships, roles and responsibilities of project team members and sequences of activities required to complete a project. A contracting approach is a specific procedure used under the large umbrella of a procurement method to provide techniques for bidding, managing and specifying a project.” (Walewski et al 2001). A project delivery method establishes the framework of all the project stakeholders’ relations and responsibilities, so as to avoid major mistake in the delivery method selection that may result in a drastic failure in the project. The analysis of PDM selection requires an understanding of the advantages and disadvantages of each PDM in achieving project success. One of the first steps in this analysis is to identify the parameters that the owners consider or should consider while selecting a PDM. A comprehensive study should include all available PDMs and all the qualitative and quantitative aspects of the project that may be influenced by the delivery method option. There are some existing decision support systems available to the owners of construction projects (Please refer to Chapter 2) but none of them is tailor-made for the transit projects and none is comprehensive in terms of the number of PDMs they consider. Several papers and PhD dissertations on PPP and its characteristics can also be found in the literature (Deng 2004; Zhang 2006b).
For example, Zhang (2006b) studies the economic aspects of PPP and concentrates on concession period and net present value calculation. Deng (2004) has developed an expert system that considers the financial aspects of project management and assists the owners of a PPP project in their decision throughout the project from its feasibility study to cash flow estimation. However, none of the previous research efforts compare PPP with other PDMs. Banks (2007) analyzes a highway extension in Massachusetts with the utilization of PPP and studies the results of the State’s first attempt to use PPP in an infrastructure project. Akintoye et al (2003) discussed risk allocation in PPP and its significance in selecting this delivery method. Several other authors have also published on the history of PPP (Zhang 2001; Diekmann 2007), advantages and disadvantages of this method (Vining et al 2005; Quiggin 2004), and a few highway project case studies (Kumaraswamy et al 2001; Ababtain et al 2003) but there is a gap for a decision support system which includes quantitative approaches and considers the most recently introduced delivery methods. There is also a need in the industry for a guide on how to select the best alternative delivery method. The author has worked on a project sponsored by the Transit Cooperative Research Program (TCRP) for the very same purpose. The TCRP 131 Guidebook introduces a reliable procedure to the transit owners who want to select a PDM from DBB, DB, CMR, and DBOM (TCRP 2009). Nevertheless, this guidebook does not include PPP and does not use NPV as quantitative factors. This dissertation expands the literature review and concentrates on the definition of PPP to provide the industry with a clear scope of this delivery method amid the inconsistency found in the literature. The addition of PPP to the list of possible PDMs for a transit project is the main contribution of this dissertation in addition to what has been already
published in the TCRP Guidebook (TCRP 2009). Adding the financial aspects of PDM selection and inclusion of quantitative risk analysis are two major elements added to the DSS to make it capable of comparing PPP with conventional PDMs such as DBB or DB. The skyrocketing oil and material prices have already changed the behavior of commuters and some previously infeasible transit projects have suddenly become economically feasible while the federal government cannot financially support them. The option of PPP will be considered more often in this atmosphere and a complete decision support system should include this option and concentrate more on economical aspects.

Research Objectives

This research provides a systematic and defensible procedure for selecting the most appropriate PDM. It also focuses on the use of PPP and attempts to answer the following questions:

- Can a project with insufficient revenue generation be a candidate of PPP?
- How should the owner compare PPP with the traditional DBB while the financial agreements and risk shares are extremely different in these two methods?
- How to make sure that PPP is the most beneficial delivery method for the public?
- How should the owner decide on the delivery methods effects on time and cost of the project when the design and specifications are not ready?

The research attempts to answer those questions by developing a decision support system for the selection of the appropriate delivery method for transit projects. This system includes DBB, DB, CMR, and PPP and will compare them using qualitative and quantitative approaches. The research aims to develop a comprehensive system which is
based on practical accumulated experience in this field coupled with a rigorous analytical and quantitative consideration of all relevant issues. The main objectives of this research are:

- Defining quantitative approaches towards project delivery method selection
- Quantifying the difference in the performances of PDMs in terms of cost and schedule
- Considering uncertainties of cost estimates and construction duration in the calculation of NPV for different PDMs
- Defining a complete set of pertinent issues that affect the PDM selection based on case studies and literature review
- Generalizing the PDM selection decision support system so that it can be used in other sectors of construction industry

**Research Methodology**

The methodology employed in this research (Figure 1.1) consists of six parts: 1) literature review, 2) interview and case study, 3) development of a list of pertinent issues, 4) development of a framework for decision support system, 5) example case application, and 6) validation.

1) **Literature Review**

An extensive literature review was carried out with the following objectives:

- Defining the PDMs available to transit agencies
- Searching for decision support systems suitable for PDM selection
\begin{itemize}
  \item Defining a set of pertinent issues that affect the decision making
  \item Searching for information on projects executed with different delivery methods
  \item Studying the approaches of other countries toward PDMs and mainly to PPP.
\end{itemize}

2) Interview and Case Study

The second step of the research was to select a number of transit projects and conduct case study analyses on them. The main objectives of the case studies were to find out the state of practice in the industry and to understand the processes and factors considered by transit agencies when they make decisions on selecting a project delivery method.

According to Yin (1984), case studies are “the preferred strategy when how or why questions are being posed. A case study essentially tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result.” The method used during the case studies was the one described by Yin (1984). The main principles of data collection in a case study were followed. These principles were a) using multiple sources of evidence, b) creating a case study data base, and c) maintaining a chain of evidence.

Yin (1984) emphasizes on the importance of planning the process of accessing and collecting data as an essential preparation for efficiently and accurately collecting cogent information. Additionally, it is equally important to carefully select cases that can be compared directly with one another and also offer cross-sectional diversity in order to test the validity of the study. The selected sample includes five Design-Build (DB) projects from four different agencies, two Construction Manager-at-Risk (CMR) projects from two different agencies and a Design-Bid-Build (DBB)/Multi-Prime project (which is actually a series of DBB projects) undertaken by one agency. The dissertation could not
include any Public-Private Partnership (PPP) project for the case study analysis mainly because there was not such a project available in the U.S.A. The structured interviews - interviews in which the interviewee (selected from the pool of experts) is informed about the questions and topics before the interview usually by sending a questionnaire - were used to collect case study data including quantitative data points regarding scope, financial and schedule information on each project. Also, the procedures and decision support systems used by transit agencies were identified during the interviews.

3) Develop a List of Pertinent Issues

The third step after collecting data from multiple sources (papers, reports, case studies and interviews) was to refine the list of pertinent issues that affect the choice of delivery method. To have a comprehensive set of factors, a proposed list of factors affecting the choice of delivery method among DBB, DB, and CMR was put together based on the literature search. Then this list was challenged during the interviews by the professionals who had previous experience in selecting a PDM for their projects. At last it was reviewed by a panel of experts in TCRP. The result was a validated list of pertinent issues that were used in developing the framework for decision support system (Please refer to Chapter 9). The same methodology in terms of literature search and interviews was employed to find out the factors affecting the choice of PPP but no case study analysis was conducted due to the lack of any completed PPP project in the US transit industry. However, the list of factors were examined, reviewed and validated during interviews conducted with several professionals and experts (Chapter 9).
4) Develop a Framework for Decision Support System

The fourth step of this research was to develop a framework of a decision support system that would apply to different delivery methods (DBB, DB, CMR, and PPP) and a structured step-by-step approach toward selecting the best and most appropriate delivery method. Here the influential factors on selecting PPP for a project (e.g. revenue generation, regulations, risks, and size) were considered in the system. This step also included a study of the nature of decision making and available decision support systems (Chapter 3).

5) Sample Case Application

The next step was the implementation of the developed decision support system to a hypothetical project in order to fine tune the system and check its practicality (Chapter 8). Extensive studies were executed on capital costs, interest rate prediction, concession period, taxes, and operation and maintenance costs. The financial calculations, risk allocation and Public Sector Comparator (PSC) studies were performed in this case study. In order to make the hypothetical project more realistic, information was collected from real transit projects but at the same time some assumptions were made so that the case study project goes through most of the steps of the proposed system.

6) Validation

The final step was validation of the suggested system (Chapter 9). The proposed decision support system was validated as a requisite model. “A model is requisite if its form and content are sufficient to solve the problem” (Phillips 1984). The specialist usually contributes the form of the model while the problem owners’ participation is mainly in
the contents of the model. The form of the model includes its structure (e.g. weighted matrix, decision tree, influence diagram) and its generic elements (e.g. outcomes, consequences). The content of the model (weights, assessment of probabilities, element linkages, etc.) should be based on the participants’ understanding of the problem itself. If the efforts of the DSS developer and the problem owners’ are well coordinated and both sides perform their roles, a requisite model is more likely to be achieved. “A requisite model is more likely to be adequate if problem owners contributing to its development represent a variety of views and if the specialist [model developer] can provide a neutral perspective and setting” (Phillips 1984).

A requisite model is inherently conditional “on structure, on current information, on present value-judgments, and the problem owners” because by definition “a model is requisite only when no new intuitions emerge about the problem” (Phillips 1984). So changes in information and other conditions may render a model not to be requisite any longer.

On the other hand, there is no benchmark to compare the results of the decision support system with. Phillips’s (1984) suggestion that the validity of the decision support system should be judged by the coherence of the decision process and not by the consequences best fits to this type of research effort. As another researcher (Oyetunji 2001) in the same field observes “production of correct results could not be used as the basis for validating the procedure and the tool [decision support system] developed” in his research. The PDM chosen for a real project in the past is not necessarily the best one for that project so any difference between the results of the proposed decision support system and the real case is per se meaningless.
Facing these challenges, the approach used to validate this multi-attribute system was to compare the results of the system with “the holistic judgment of the people” (Phillips 1984). In this approach, the system should be introduced to the professionals who are ultimate decision makers on the problem under consideration (selecting an appropriate PDM in this case) and their feedbacks after implementing the system should be collected and analyzed. This way, the sufficiency of the system in terms of including all the influential factors on decision as well as all the possible options to choose from, is tested. Figure 1.1 illustrates the flow of data and sequence of methodology.

Figure 1.1. Flow of Data and the Research Methodology
Dissertation Chapters

The Dissertation is divided into 10 chapters. Although each chapter serves its own purpose, the main goal of this dissertation (developing a DSS for PDM selection) is always followed throughout the text.

Chapter 1 introduces the scope of the research, its chapters and its major objectives. It also identifies the current challenges and the questions to be answered and explains the research methodology with which project goals are achieved.

Chapter 2 presents the definition of relevant terms and concentrates on the evolution of alternative delivery methods. It includes precise and distinguishing definitions for DBB, DB, CMR, and PPP. The chapter also defines the major characteristics of projects in transit industry. These definitions clearly define the bases for the scope of this dissertation.

Chapter 3 starts with an overview on the available project delivery method (PDM) selection systems that are developed over time for other types of projects (e.g. buildings). It then studies the sequence of decision based on the project life cycle and analyzes the critical factors affecting a PDM selection. At the end of this chapter the framework of the proposed decision support system is introduced.

Chapter 4 concentrates on the first tier of conventional PDM selection. This tier is based on 24 issues which are introduced and categorized in this chapter. The advantages and disadvantages of conventional PDMs (DBB, DB, and CMR) are analyzed with respect to these 24 issues. Then an analytical approach to select a PDM is introduced.
Chapter 5 discusses the second tier of conventional PDM selection. This chapter introduces two procedures for this purpose: weighted matrix and Analytic Hierarchy Process (AHP). The chapter also shows how to determine the weights and how to make sure they are consistent.

Chapter 6 is about the final (third) tier of conventional PDM selection. It is a risk-based approach and is divided into qualitative and quantitative methods. The chapter explains the procedures for each of these methods and provides examples to better illustrate the application.

Chapter 7 deals with the comparison of the PPP with other project delivery methods. It first reviews the available procedures for evaluating PPP option. Then it divides the decision into two stages: before advertisement and after receiving the bids. The chapter introduces a set of factors to be considered in the first stage and also a procedure to be used in the second stage. The concept of Value for Money (VfM) is introduced in this chapter and its calculations as well as its challenges are discussed.

Chapter 8 introduces a hypothetical project on which the proposed decision support system is applied to identify the most appropriate PDM. This chapter illustrates the applicability of the proposed decision support system. It illustrates the procedure and details of the method.

Chapter 9 presents the validation of the proposed DSS. Any decision support system should be validated to make sure all the major factors are considered and the procedures are reliable and results are consistent. This chapter explains how this DSS was validated through internal reviews, interviews, and panel reviews.
Chapter 10 is the conclusion of the dissertation. It highlights the contributions of this research effort and emphasizes on the advantages of the unique DSS proposed in this dissertation while considering the difficulties and challenges. It also provides recommendations for further research.

The dissertation has an appendix (Appendix A) for the introduction of all references used in this dissertation.
Chapter 2. Project Delivery Methods in Transit Industry

Introduction

In the recent decades, owners of construction projects have been applying pressure on the architecture/engineering/construction (A/E/C) industry to improve quality, reduce cost, and more importantly compress the project schedule for all of the public and private facilities. To fulfill these objectives, owners, designers, builders and other members of the construction industry have experimented with various forms of project. The adoption of alternative project delivery methods has added to the challenge of selecting the method most appropriate to the owner’s needs and technical requirements of the project. Several associations and professionals have given their own definitions of PDMs practiced in the industry (Walewski et al 2001; Associated General Contractors of America (AGC) 2004; American Council of Engineering Companies (ACEC) 2005). These documented definitions do not necessarily comply with each other and one may find minor or even major differences in them. It becomes even more complicated when some authors combine the payment methods, procurement methods, and management methods with the PDMs. As a result, this part of the research provides a set of standard PDM definitions as a basis for communicating the technical requirements of bringing a new project from the owner’s concept to operating phase and final decommissioning.

Conventional Project Delivery Methods Definitions

Project delivery method is a term used to refer to all the contractual relations, roles and responsibilities of the entities involved in a project. The Texas Department of Transportation (TXDOT) defines project delivery method as follows: “A project delivery
method equates to a procurement approach and defines the relationships, roles and responsibilities of project team members and sequences of activities required to complete a project. A contracting approach is a specific procedure used under the large umbrella of a procurement method to provide techniques for bidding, managing and specifying a project.” (Walewski et al 2001). The Associated General Contractors (2004) defines project delivery method as “the comprehensive process of assigning the contractual responsibilities for designing and constructing a project. A delivery method identifies the primary parties taking contractual responsibility for the performance of the work.” Thus different project delivery methods are distinguished by the way the contracts between the owner, the designer, and the builder are formed and the technical relationships between each party within those contracts.

There is also a distinction between the delivery method and the management method. The management method “is the mechanics by which construction is administered and supervised” (AGC 2004). This function is either retained by the owner agency or is outsourced. An example of outsourcing the management process is hiring an agency Construction Manager (CM) to represent the owner’s interests during design and construction. Theoretically any management method may be used with any delivery method (i.e. the owner may hire an agency CM to manage a DBB, DB, or even a CMR project). Some authors (Alhazmi et al 2000; Oyetunji et al 2006) have combined procurement methods with delivery methods. Procurement methods equates to the procedures through which a designer or a constructor is selected for the project. Some of the most practiced procurement methods are lowest bid, best value, and qualifications-based selection. Although any combination of procurement methods and delivery
methods has its own characteristics, mixing these two categories would be counterproductive and confusing. Payment methods (e.g. fixed price, unit price, GMP, cost plus fee) have similar interaction with project delivery methods. The choice of a payment method specially affects the risk allocation in a project but this dissertation distinguishes between project delivery methods and payment methods and does not combine them together. The table below (Table 2.1) shows some of the PDM categorizations found in the literature.
<table>
<thead>
<tr>
<th>ACEC</th>
<th>AGC</th>
<th>Oyetunji &amp; Anderson</th>
<th>Mahdi &amp; Alreshaid</th>
<th>Garvin</th>
<th>Konchar &amp; Sanvido</th>
<th>TCRP</th>
<th>Dorsey</th>
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<tr>
<td>Major delivery systems:</td>
<td>Major delivery methods:</td>
<td>* Design-Bid-Build</td>
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<td>* Design-Bid-Build</td>
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<td>* DBB with early</td>
<td>* DBB with project</td>
<td>* DBB with early procurement and construction manager</td>
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<td>* Design-Build</td>
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<td>procurement</td>
<td>manager</td>
<td>* O&amp;M services</td>
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<tr>
<td>* Construction Manager at Risk</td>
<td>* Construction Manager at Risk</td>
<td>* Construction</td>
<td>* O&amp;M Services</td>
<td>* Build Operate</td>
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<tr>
<td>* Construction Manager at Risk</td>
<td>* Construction Manager at Risk</td>
<td>* Management</td>
<td>Operate</td>
<td>Transfer</td>
<td>* DBOM</td>
<td></td>
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<tr>
<td>* Construction Manager at Risk</td>
<td>* Construction Manager at Risk</td>
<td>* Agency</td>
<td>* Program Manager at Risk</td>
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<tr>
<td>* Indefinite Delivery/Indefinite Quantity (IDIQ)</td>
<td>* Indefinite Delivery/Indefinite Quantity (IDIQ)</td>
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<td>* Fast track</td>
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</table>
Although different categorizations for PDMs are found in literature (Table 2.1), this research follows the classification done by Construction Industry Institute (CII) and Associated General Contractors (AGC) in which there are essentially only three fundamental project delivery methods: DBB, DB, and CMR (CII 1997; AGC 2004). There is a multitude of various names for PDMs throughout the industry which are mainly hybrids or modified versions of these methods. The main reason for categorization of PDMs similar to every other categorization is to help better understand and then predict the behavior and characteristics of items in one category. Given this philosophy, the significant differences between the PDMs should be found in the scope of responsibilities of parties involved, risk sharing mechanism, and sequence of activities. This approach would result in the same categorization of PDMs into DBB, DB, and CMR. For example, agency construction manager is considered as a PDM in a few papers (Table 2.1), while it is essentially a management method and the risk sharing mechanism does not change after bringing an agency construction manager on board. An another example DBB, multiple prime and staged DBB are considered to be different PDMs by Oyetunji and Anderson (2001) but there is no significant difference in the scope of responsibilities between DBB and staged DBB or multiple prime. Therefore, this research will focus its information in those three categories.

In addition to conventional delivery methods (DBB, DB, and CMR), another PDM, namely Public-Private Partnership (PPP) will be considered as an option for the owners who seek private financing for their projects. It should be noted that PPP is essentially a kind of DB with the addition of financial and operation agreement during the concession
period. Further illustrations including definitions and a brief explanation of distinguishing characteristics of each delivery method will be given in the following parts.

Addition of PPP to the list of PDMs and expanding the discussion so that this delivery method is compared with more conventional methods is mainly because of emerging trend towards the use of PPP in transit projects. Although the private sector in the US has not been involved in any partnership with the federal or state governments in financing a transit project, the trend of studies on the possibility of PPP application to transit projects and several reports published by the Department of Transportation (USDOT 2004; USDOT 2007) clearly shows that the lack of public finance and huge deficit of state transit agencies on the one hand and the increasing public demand for new transit projects on the other hand has left the government with very few options. PPP is an option which has shown its advantages in other countries. The use of PPP (PFI) in London underground is well documented in the literature and several reports on the performance of this delivery method have already been published (Akintoye et al 2003). The use of PPP in Canada and South America (Abdel Aziz 2007a; Phang 2006) illustrates the possibility of PPP application to transit projects. The US transit agencies can see the PPP as a means of borrowing money from the private sector investors now and involving them in an infrastructure project. The money will be paid back during the project operation (30 years and more). At the same time, the private sector’s money is at risk because the government’s payment is dependent on the performance of the transit line. The government can even assure the quality of the service by linking the payment to some measurable factors in operations phase (e.g. delays in service).
Design-Bid-Build (DBB)

DBB is the traditional project delivery method in which an owner procures the project design through a designer and then advertises and awards the separate construction contract based on the designer’s completed construction documents. The owner is responsible for the details of design and warrants the quality of the construction design documents to the construction contractor.

The owner of a DBB project “owns” the details of design during construction and as a result, is financially liable for the cost of any design errors or omissions encountered in construction. This principle is called the “Spearin Doctrine” (Mitchell 1999). The construction phase of DBB projects is generally awarded on a low bid basis. There is no incentive for the construction contractor to minimize the cost of change orders in this delivery method. In fact, there can be quite the opposite effect. A construction contractor who has submitted a low bid may need to look to post-award changes as a means to enhance profit on the project after bidding the lowest possible margin to win the project. One author states that the defining characteristics of DBB are as follows:

- “There are separate contracts for design and construction
- Contractor selection is based entirely on cost
- Design documents are 100% complete” (Bearup et al 2007).

DBB projects can also be awarded on a negotiated basis and a best-value basis (Scott et al 2006). In both cases, the probability that the project will be awarded to a builder who has submitted a mistakenly low bid is reduced. Additionally, the motivation of the construction contractor in both cases is to complete the project in a manner that will get it
invited back to receive the next negotiated. Regardless of the award method, DBB is distinguished by less builder input to the design than DB or CMR. Thus, the owner must rely on the designer or agency CM (and not the builder) for constructability review if there is any at all. Nevertheless, in this method the owner has full control over the details of design which is often a requirement for some complex projects.

DBB is also characterized by the high level of competition in both the design and construction phases. All qualified designers are able to compete for the design without restriction. Additionally, all construction contractors who are able to furnish the requisite bonding are also able to compete without constraint. Design subconsultants and construction trade subcontractors are also able to compete with minimal restrictions. Finally, as DBB is normally viewed as the traditional project delivery method in the US, it is both well-understood and well-accepted by both owners and members of the design and construction industries.

*Construction Manager-at-Risk (CMR) or Construction Manager/General Contractor (CM/GC)*

CMR projects are characterized by a contract between an owner and a construction manager who will be at risk for the final construction cost and schedule. In this agreement, the owner authorizes the construction manager to responsibly manage the details of a project’s life cycle to fulfill the owner’s objectives. CMR contracts can contain provisions for the CMR to handle some aspects of design, but generally, the owner retains the traditional responsibility by keeping a separate design contract and
furnishing the CMR with a full set of plans and specifications upon which all construction subcontracts are based.

The idea of CMR is to furnish professional management of all phases of a project’s life to an owner whose organization may not have those capabilities. Typically, CMR contracts contain a provision in which the CMR stipulates a guaranteed maximum price (GMP) above which the owner is not liable for payment. Often these contracts include incentive clauses in which the CMR and the owner can share any cost savings realized below the GMP. The CMR will usually be paid for furnishing preconstruction services such as cost engineering, constructability review, and development of subcontractor bid packages.

According to AGC (2004) the defining characteristics of the CMR are the followings:

- The designer and the CMR hold separate contracts with the owner
- The CMR is chosen based on criteria other than just the lowest construction cost, such as qualifications and past performance.

Additional defining characteristics are:

- “CMR contracts directly with trades and takes on ‘performance risk’ (cost and schedule commitments)
- Schedule allows for overlapping design and construction
- Owner procures preconstruction services from the CMR
- Owner expects CMR to provide Guaranteed Maximum Price (GMP) and to commit to delivery schedule” (Bearup et al 2007)
• “Transparency is enhanced, because all costs and fees are in the open, which diminishes adversarial relationships between components working on the project, while at the same time eliminating bid shopping” (AIA 2005).

CMR facilitates phased construction if that is a requirement for a given project. Unlike DBB, CMR brings the builder into the design process at a stage where definitive input can have a positive impact on the project. In CMR, the construction manager essentially becomes the general contractor at the time the guaranteed maximum price is established. While some experts attempt to distinguish between CMR and Construction Manager/General Contractor (CM/GC) due to perceived levels of risk, many agencies use these terms more or less interchangeably. According to AGC (2004) there has been some confusion about terms CM-at-risk and CM/GC because of the assumption that the phrase at-risk connotes cost guarantee. Even if there are no cost guarantees, the CM is still at-risk because the CMR holds the trade contracts (warranting the performance of the work). Because of this, some users choose to avoid the debate over the term risk and instead use the term CM/GC. The CMR can provide realistic project cost estimates early in the project life cycle. It is anticipated that after a certain amount of design is complete and the project is sufficiently defined, the owner will enter into a contract with the CMR for providing construction services. Many states reserve the right to go out for bid if they think that the CMR’s price is not competitive (Minchin et al 2007).

There are two types of CM arrangements, namely Agency CM and CM-at-risk. The emphasis in this dissertation is CM-at-risk. Agency CM is not a project delivery method as the CM is not contractually responsible for delivering the project. Its role is purely consultative and is usually not at risk for the cost and schedule of building the project.
As the design selection process virtually mirrors the same process in DBB, implementing CMR does not inherently restrict competition among designers and design subconsultants (AIA 2005). Owners occasionally require the designer in a CMR project to have previous CMR experience, which will impose a constraint on competition, but only if the owner chooses to do so. As the construction contractor is selected on a basis of qualifications and past performance and must also have the capability to perform preconstruction services, CMR project delivery can constrain competition to those constructors that have previous CMR experience. Most public CMR laws require competitively bidding out the construction trade subcontract work packages. The central idea of CMR is to get the advantage of price competition in the subcontract packages combined with the quality-based selection of the GC as CMR.

*Design-Build (DB)*

Design-Build is a project delivery method in which the owner procures both design and construction services in the same contract from a single, legal entity referred to as the design-builder. A variety of methods exist for selecting the design-build contractor. The more common procurement methods in DB are the one-step and the two-step process. The one-step process provides for competitive evaluation of technical proposals, with the contract award decision based on best value to the owner agency. The best value is based on a combination of technical merit and price (Molenaar *et al* 1999). The two-step process separates the technical proposal from the price. The method typically uses request for qualifications (RFQ)/request for proposal (RFP) procedures rather than the DBB invitation for bids procedures.
There are a number of variations on the DB process, but all involve three major components. The owner develops an RFQ/RFP that describes essential project requirements in performance terms. Next is the evaluation of proposals, and finally, with evaluation complete, the owner must engage in some process that leads to contract award for both design and construction services. The DB entity is liable for all design and construction costs and normally, must provide a firm, fixed price in its proposal (El Wardani et al 2006; Ibbs et al 2003; Graham 1997). As in CMR, the builder has early constructability input to the design process. As the owner no longer owns the details of design, its relationship with the design-builder must be based on a strong degree of mutual professional trust (Beard et al 2001). The design-builder literally controls the project delivery process. As a result, DB is the delivery method which has the greatest ability to compress the project delivery period and as a result is often used for “fast-track” projects.

Bearup et al (2007) state that the defining characteristics of DB are as follows:

- Single point of responsibility
- Schedule allows for overlapping design and construction
- Design-builder furnish preconstruction services during design
- Owner expects design-builder to provide a firm fixed price and to commit to delivery schedule.

DB creates the greatest constraint on competition in that all parties to the DB contract are selected using qualifications and past performance as a major selection factor. As the
owner transfers responsibility for all design and construction in the DB contract, it also loses the ability to foster competition between design subconsultants and construction trade subcontractors. There is typically no requirement to competitively bid for subcontract work packages and often the scale, complexity and speed at which DB projects are executed precludes firms with no DB experience from being able to participate. Additionally, as the contract is awarded before design is complete, DB can also create an unfavorable risk environment for subcontractors whose cost estimating systems lack the sophistication to be able to price work without competed construction documents.

Public Private Partnership (PPP)

The governments have faced increase in public demands for infrastructure facilities (e.g. highways, railroads, schools) while the economic growth has slowed down and the taxes have reached their highest affordable rates. The accumulated deficit has also put pressure on governments and has made them resistant to increase the ratio of debt to income in their countries. In this environment, cutting back on some public services and seeking new sources of finance have been the approaches many countries have followed. Evolution of Public-Private Partnership (PPP) is essentially a result of these developments (Quiggin 2004).

The term “Public-Private Partnership” (PPP) refers to several different types of public and private sector agreements. Variety in PPP is so overwhelming that getting to a unique definition for PPP has become difficult (Akintoye et al 2003). The United States Department of Transportation (USDOT) has the following definition for the PPP. “PPPs
contemplate a single private entity, typically a consortium of private companies, being responsible and financially liable for performing all or a significant number of functions in connection with a project.” (USDOT 2004). The USDOT reports to Congress (2004 and 2007) expand the PPP so that it covers other methods such as design-build. This definition distinguishes PPP from other collaborative arrangements between public and private sector that are simply pumping private capital into the infrastructure projects, *i.e.* privatization. PPP is different from privatization because with privatization the government does not have a direct control over ongoing operation, whereas with a PPP the government retains the ultimate responsibility (Grimsey and Lewis 2005a). Based on these reports some of the major types of PPP are Build-Own-Operate (BOO), Design-Build-Finance-Operate-Maintain (DBFOM), Design-Build-Finance-Operate (DBFO), Build-Operate-Transfer (BOT), Design-Build-Operate-Maintain (DBOM), and Design-Build (DB) (USDOT 2007). Even USDOT documents are not consistent in defining PPP. For example a recent report of Federal Highway Administration (FHWA 2009) defines PPP as “a contract between the public and private sectors for the delivery of a project or service in which the private sector has responsibility for acquiring the majority of the necessary financing.”

As another example, the UK government divides PPP into eight types: 1) Asset sale, 2) Wider market, 3) Sales of business, 4) Partnership companies, 5) Private Finance Initiative (PFI), 6) Joint ventures, 7) Partnership investments, and 8) Policy partnerships (Li *et al* 2005b). Among all of the above types, PFI has been used more than others and many recognize PPP in the UK by this type. PFI is an arrangement between public and
private sector in which the private entity constructs and maintains the public project by using private finance (HM Treasury 2006).

The Canadian Council for Public Private Partnership defines PPP as “PPP is a cooperative venture between the public and private sectors, built on the expertise of each partner that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards.” (http://www.pppcouncil.ca)

Akintoye et al (2003) quote Savas’s definition (2000) of PPP: “any arrangement between a government and the private sector in which partially or traditionally public activities are performed by the private sector.”

The National Council for Public Private Partnership gives the following definition for PPP: “A Public-Private Partnership is a contractual agreement between a public agency (federal, state or local) and a private sector entity. Through this agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public. In addition to the sharing of resources, each party shares in the risks and rewards potential in the delivery of the service and/or facility.” (http://www.ncppp.org)

Australians (namely State of Victoria) define PPP as an alternative means of providing public infrastructure in which “the government would engage one private party to design, construct, finance, maintain and at times operate the facility.” (Maguire et al 2004).

The level of control and financial involvement are the main defining factors of PPP in the guidebook issued by the European Commission (2003). They give the following definition for PPP: “A Public Private Partnership is a partnership between the public
sector and the private sector for the purpose of delivering a project or service traditionally provided by public sector.”

Gerrard (2001) believes that the major factor in a PPP project is the private sector capital being at risk. “At the heart of PPPs is the deployment of private sector capital. Within a PPP framework, this can result in greatly improved value for money for the government in terms of the risks transferred to the private sector and powerful private sector incentives for the long-term delivery of reliable public services.”

A significant factor that divides the PPP approaches into two main categories is the financial element of the agreement. One category is based on an agreement between the public and a private entity that will provide financing for the project. The other category is service-based and is mainly evolved to use the private sector skills in effective design, construction and management of a project (Abdel Aziz 2007b).

PPP in this dissertation refers to the first group; it will always have a financial involvement of private sector. In other words, the Australian definition for PPP is adopted based on which the private party is involved in project finance as well as its design and construction. The public entity selects a private entity in a competitive environment and awards the project to the private entity. The private partner finances and designs the project and then builds it and usually operates the facilities developed. The private sector can be compensated in several ways. For example, the public entity may buy the service or goods produced by the project (e.g. electricity). The government (public agency) may authorize the private sector to collect tolls or fees directly from the users (e.g. toll roads). Another option is to give the private partner some tax credits.
Awarding the private entity real estate rights and an authorization to develop them is an appropriate option for railroad projects (it is usually referred to as Transit Oriented Development). It should be mentioned that transportation PPP projects are very large and complex and their agreements are also complicated. The public entity usually shares the capital costs with the private partner and the payment methods are often a combination of a number of aforementioned possibilities (based on the nature of the project). The PPP payment mechanisms are further explained in this chapter.

A PPP is an approach of delivering a public service with the involvement of private sector in its development as well as its financing. The main emphasis in PPP is on government (public) service and not the assets (Earl 2003; Grimsey et al 2005a). In other words, the government attempts to deliver some services through the private sector and ownership of the facilities is not the government’s first priority. An independent entity is sometime evolved as a result of a PPP agreement that legally owns the project assets and all the constructed facilities.

*The Evolution of PPP*

There is no clear starting point for the method nowadays referred to as PPP. Some authors even believe that the construction of Suez Canal in 1869 was done with a method similar to today’s public-private partnership (Kumaraswamy et al 2002; Diekmann 2007). Attracting private funds to infrastructure projects through new methods has been sought by public agencies as a response to the shortcomings of traditional ways of delivering infrastructure projects (FHWA 2005). As a response many governments around the world started to privatize the public assets and projects in the 1970s and 1980s
(e.g. selling out the Telecom in the United Kingdom) but the process stopped in pioneer countries like the UK and Australia for several reasons, one being the lack of attractive public assets for private investors. Then Private Finance Initiative (PFI) was introduced in the UK in 1992 (Broadbent et al 2003). Australia and New Zealand soon followed the UK and launched their new program which were more than just selling out the public assets to the private sector and were indeed Public Private Partnerships. A turning point in the process of privatization happened in 1990s when the Ryrie Rules required the consideration of a factor called “value for money” for any attempt of privatization and tried to guarantee that the cost of privatization for the public would be lower than the provision of the same service through traditional ways (Quiggin 2004). Value for Money is defined by HM Treasury (2006) as “The optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user’s requirements.” Private sector participation in infrastructure projects during the 1980s and 1990s show that the private sector has benefited from the desperate need of the governments for new financial sources. Rules and regulations of PPP changed in the UK with time and mainly after the change in the government. For example Blair’s administration modified and re-introduced the Private Finance Initiative (PFI) which was first introduced in early 1990s in Major’s administration. “The crucial innovation in the modified PFI is the introduction of PSC [Public Sector Comparator] as a device for ensuring value for money” (Quiggin 2004). Australia has used the same method in the 21st Century and State of Victoria has issued a series of guides and technical notes for private partnership. These publications are used by others in Australia and even to certain extents in Canada (Industry Canada 2002). As a matter of fact there are lots of similarities
between the approaches that the UK and State of Victoria in Australia have adopted and
as Industry Canada states their PPP programs “were developed based on central policies
accompanied by tools and a more mature market” (Industry Canada 2002).

China, the Netherlands, Canada, Germany, Finland, Turkey, South Africa, Hong Kong,
Ireland, and France are some of the countries that use PPP for their infrastructure projects
(Abdel Aziz 2007b; Klijn et al 2003; Broadbent et al 2003; USDOT 2004;
Kumaraswamy et al 2002). HM Treasury claims that more than 50 countries have
consulted with it for implementing the PFI in their countries (HM Treasury 2000).

Evolution of PPP in the USA does not have the same starting point. The US did not need
to launch any privatization program. Many public services in the US were already
provided through private sector (Broadbent et al 2003). However, the very same reasons
of budget deficit, aging bridges and facilities, and high demand for new highways led the
US government to issue a set of regulations in 1991 (Intermodal Surface Transportation
Efficiency Act (ISTEA)) which allowed the use of several types of PPP (based on
USDOT definition of PPP) in toll road projects. The ISTEA required each state to pass
its own enabling legislation for better implementation of PPP projects (Zhang et al 2001).
However, a new research shows that only 24 states have authorized their DOTs to use
PPP in transportation projects (Ghavamifar and Touran 2008).

Private sectors under the ISTEA were allowed to own toll roads and the states were
authorized to “loan the Federal share of a project’s cost to another public agency or
private entity constructing the project” (USDOT report to Congress 2004). Special
Experimental Project (SEP-14) was another law that facilitated the use of new methods of
infrastructure construction, PPP included. It was aimed to identify and document methods that have the potential to reduce the life cycle costs of projects. The Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was another influential law passed in 2005 to facilitate the formation of PPP projects. The US Congress has pushed for the implementation of private partnership methods in transportation projects during the past decade. Two detailed reports of USDOT to congress in 2004 and 2007 are prepared upon the Congress requests. These reports show the progress, case studies, relevant laws and regulations and barriers of implementing PPP in transportation projects. A major step forward in the implementation of PPP in transit projects occurred in 2006 when Public Private Partnership Pilot Program (Panta P) was passed. This pilot program intended to demonstrate the advantages and disadvantages of public-private partnerships for certain new fixed guideway capital projects funded by the Federal Transit Administration (FTA). “In particular, the Pilot Program is intended to study whether, in comparison to conventional procurements, PPPs better reduce and allocate risks associated with new construction, accelerate project delivery, improve the reliability of projections of project costs and benefits, and enhance project performance” (FTA 2007). A synthesis published by National Cooperative Highway Research Program (NCHRP 2009) and another survey of international cases of PPP application in highway projects (FHWA 2009) shows the trend towards the use of PPP in highways. The major barrier for transit projects is that they are not money makers and a government subsidy is required to make them financially attractive. Nonetheless, a number of the cases in the aforementioned reports are built with the guarantee of public
sector. For instance, the government minimum revenue (not tied to the number of cars using the highway) is guaranteed for the private sector (FHWA 2009).

As it is mentioned in the definition part of this research, PPP in the DOT terminology is used in such a general way that it includes DB or DBOM. Because of that, the progress reports and case studies in these reports refer to some projects without any financial input from private sector, e.g. Hudson-Bergen Light Rail Transit Line which was a DBOM project. Accordingly, although these reports have several examples of implementing PPP in transit projects, there is no financial participation from private sectors in these projects.

“The only urban fixed guideway project since the 1920s with financing based in large on projected farebox” is Las Vegas Monorail which was completed in 2004 (USDOT 2007) but has experienced safety, operation and ridership problems ever since. Another more recent attempt is Dulles Corridor. The Dulles Corridor Metrorail Project is a 23.1 mile extension of Metrorail in the Commonwealth of Virginia, including 11 additional Metrorail stations. Its first phase (11.6 miles) was planned to be built with a PPP agreement. However, after a long negotiation process, the project started under a DB contract simply because the public sector could not reach a financial agreement with the private sector. Canada Line in Vancouver is a good example of PPP in North America. This transit project has “19.5 km tracks, 16 stations, 2 bridges, and 9 km tunnel.” “The government signed a 35-year agreement in 2005.” The total estimate for the project was $2.05 billion and the government participated in capital costs by gradually paying $1.33 billion of the costs after achieving certain milestones during the construction. (Abdel Aziz 2007a).

In order to collect professionals’ opinion on the definition of PPP 8 interviews were conducted for this research (Please refer to Chapter 9 for more details of the interviews) in which they were asked to choose the actual forms of PPP among a) Private contract fee services, b) Design-Build, c) Design-Build-Operate-Maintain, d) Long-term lease agreement, e) Design-Build-Finance-Operate, f) Build-Own-Operate, and Transit Oriented Development. The results of the interviews show that “private contract fee services” is not a PPP. Some of the professionals consider “Design-Build” as a PPP method. Risk allocation was the distinguishing factor. “Design Build Operate Maintain” was considered as similar to Design-Build. “Long term lease agreement” and “Build Own Operate” were also other methods that were considered as PPP if the private sector was involved in project finance. “Design Build Finance Operate” was the only method that most of the interviewees considered as PPP. They mentioned that “taking financial risks by the private sector” is the distinguishing factor for PPP. The interviewees believed that the private sector should be financially at risk and private sector money should be invested in the project. Transit Oriented Development was considered as PPP by half of the interviewees but in general the important factor was again the risk allocation. Based on the results of the interviews and the definitions of all the conventional delivery methods, the Australian definition of PPP is adopted in this research in which the financial element of this delivery method is specified. They define PPP as a method in
which “the government would engage one private party to design, construct, finance, maintain and at times operate the facility.” (Maguire et al 2004). Another major reason for this selection is the importance of this element in decision making. The financial element is a major driver in decision making and an important reason for selecting PPP as the most appropriate delivery method. Combining other delivery methods (such as Design-Build and Design Build Operate Maintain) with PPP and referring to the whole set as PPP is not constructive for decision makers mainly because they should be able to distinguish between the delivery methods with and without financial element embedded in their structure.

Public Private Partnership Benefits for the Owners

Public owners benefit from the PPP method in several ways. Its evolution has been in part due to financial shortage of the governments. PPP will eliminate the necessity of huge capital outlays at the beginning of the project. Based on the results of a survey Akintoye et al (2003) showed that saving in capital cost has been one of the top two reasons why local government officials in the US have chosen partnership in infrastructure projects. The UK guidelines (HM Treasury 2000) state a governmental entity develops PPP for three broad objectives: 1) to deliver improved public services by increasing the investment and quality level of management, 2) to release the full potential of public sector assets, and 3) to distribute the benefits of the PPP among all the stakeholders including the customers and users of the service provided. Another advantage of PPP for the owner is risk reduction (Akintoye et al 2003). This delivery method can transfer a wide spectrum of project risks to the private sector. The followings are some of the benefits of PPP for the owner:
a) Reduce project life cycle cost:

The inclusion of operation and maintenance phase with a design-build contract in PPP makes strong incentives for the private sector to reduce the project costs. Akintoye et al (2003) quote that the average savings of PFI projects in the UK has been around 17%. Grimsey and Lewis (2005a) report several reviews of PPP/PFI projects in which the shortcomings of traditional methods are clear when compared to the performance of PPP/PFI method. For example, an HM Treasury (2003) review of 61 projects (including prisons, schools, roads, light rails, etc.) showed that all of them were performed within budget. Besides the incentives of PPP method, innovation, economies of scale, and schedule compression contribute in project savings (European Commission 2003; Akintoye et al 2003; Vining et al 2005).

b) Accelerate project schedule:

An HM Treasury review (2003) of 61 PFI projects shows that 89 percent of them were delivered on schedule or ahead of it. This is a marked improvement over delivery time in other types of delivery methods. PPP can shorten the project schedule because it makes possible to have some overlap of design and construction. It decreases the number of bid and award processes. Dependence of private sector revenue to the commencement of operation phase motivates the contractor to finish the construction as soon as possible (European Commission 2003; Akintoye et al 2003).

c) Transfer and allocate project risks:

The ideal in risk allocation is to allocate risks to whoever is best able to manage it. Project risks in PPP have a wider range and include operation, marketing and demand,
regulation, and service satisfaction as well as design specifications and construction risks (Quiggin 2004; Vining *et al* 2005). The average value of transferred risks on PPP projects across Australia is reported to be around eight percent (Grimsey and Lewis 2005a). Transferring many of the project risks to the private sector in the PPP method is one of its main benefits to the owners (NCHRP 2009) but the key point is that the private sector should be paid for undertaking some of the project risks. In other words, although PPP makes it possible to transfer many of project risks to the private sector, it does not do it for free and the private sector expects to have an increase in its return of investment and acceptance of project risks (Hodge 2004a). PPP risk allocation will be explicitly discussed in other parts of the research.

d) Improve project integration:

PPP agreement in comparison with other delivery methods is more comprehensive and includes the design, construction, operation and maintenance of the project. It even involves the project financing. This inherently improves the project integration and design innovation while reducing the adversarial relations between different parties involved in a project (USDOT 2007).

e) Improve the quality of service:

Due to the size, complexity and scope of PPP projects, larger and more sophisticated bidders are attracted to these projects. They usually bring with them new skills, technology and knowledge to the project (Akintoye *et al* 2003). These factors in addition to the agreement incentives and higher project integration often result in a higher quality of services in PPP projects (European Commission 2003; H.M. Treasury 2000).
f) Utilize additional financial resources:

Execution of projects which are traditionally public with private financial resources is arguably the most important benefit of PPP. At least it has been the main reason for its development worldwide. Although PPP is not simply a method of project finance, it helps the government start new infrastructure projects with the utilization of new resources. PPP will eliminate the necessity of huge capital outlays at the beginning of the project and also decreases the government financial deficit resulting from project costs in its life cycle (Vining et al 2005).

Although the benefits of PPP for the owner are considerably high, this is not the only way of financing and delivering a project and not every project is a good candidate for PPP. It is not a miracle or a quick fix (European Commission 2003) and its use should be carefully assessed.

**PPP Payment Methods**

The construction and operation of an infrastructure transit project such as a commuter rail has traditionally required a significant up-front investment by the public entity in form of payments to designers, contractors, vendors, etc. The payments to the designer and the constructor have been based traditionally on their inputs to the project. For example, the designer receives its payments after each phase of the project design being approved by the owner. The constructor would similarly be compensated throughout the construction phase based on the project progress (some variations occur based on the wording of the contracts). In general, the payments in more traditional delivery methods are to compensate the contractor (designer or constructor) for the job done. The constructor in
specific receives its capital investment back from the owner based on the quantity of the work, material, labor, and service input into the project progress. Funding constraints and governmental agencies’ deficits introduced new approaches such as Public-Private Partnership (PPP) for the delivery of an infrastructure project. The owners usually choose to build the project under PPP method simply because they can not afford the heavy up-front investment required in other delivery methods. The Public-Private Partnership (PPP), however, is based on the provision of a public service which is handed to the private sector for a defined period, in return for access to an agreed revenue stream.

There are several inherent differences between the PPP and other delivery methods that may affect the payment method. Concentration on the availability of service to the public rather than construction and ownership of new facilities, awarding the long-term operation period to the contractor, unavailability of up-front investment funds, and concerns about the quality and safety of the facility during the operation have all contributed in evolving several new payment mechanisms for PPP delivery method.

There are essentially three major payment mechanisms (beside capital payment) available for the PPP:

1) Usage payments
2) Availability payments
3) Performance and safety payments

These mechanisms are developed around the idea of facility usage, availability of service, and performance, safety and quality of the service.

1) Usage payment
In this mechanism the PPP contractor receives compensations based on the usage of the facility. It is applicable where consumers are expected to pay a fee/toll/charge for the usage of a facility, for example toll roads, railways, and public utilities (e.g. water, gas, electricity). This mechanism has the potential to operate without the government subsidy. The contractor may directly receive payments from the private users of the infrastructure or service; or may receive payments from the government agency that vary according to how much the infrastructure or service is used. The latter version of usage payment in toll roads is called “shadow toll” in which the government pays a toll per vehicle per road mileage instead of the end users paying the toll (Abdel Aziz 2007a).

The contractor in this mechanism needs to satisfy users to increase its income from the project. At the same time the public agency should provide incentives to the contractor to enhance the quality of service. Due to the volatility in the number of users some sort of revenue guarantees may be needed in usage payment mechanism in order to attract private sector.

2) *Availability payment*

This mechanism is based on the facility being available for use when needed, with penalties if all or part is not available. The contractor is compensated according to the availability and performance of the service (e.g. highway lanes). This mechanism demands a comprehensive project performance specification that can explicitly define the acceptable level of performance of the facility in its operation phase. There can be several unavailability criteria defined for a project such as noncompliance with safety
regulations, inadequate lighting (for highways), delays in services, and interruption in service.

3) **Performance and safety payment**

This mechanism is mainly developed to address some of the shortcomings of other payment mechanisms with respect to the safety and quality of the service provided by the project. The owner in this mechanism can tie a certain portion of the payment to a comparison of the actual accident statistics to those of comparable roads or to an average local rate (Abdel Aziz 2007a). Performance payment should be based on the achievement of standards that are practically measurable during the contract period (Ministry of Finance of the Czech Republic 2000). In order to guarantee the quality of the performance a significant element of payment can be related to quality of performance delivery. Performance factors vary between projects, but typical factors include reliability, speed of response to failures, cleanliness, responsiveness to user comments, system monitoring, inspection and testing, user surveys, and staff feedback.

**Capital payment**

A major distinguishing factor between PPP and other delivery methods is the project finance. The PPP contractor is responsible for the finance of the project. Any investment at the beginning of the project should be from the contractor’s financial sources. The public owner should compensate the investment over the contract duration that would be as long as several decades. However, some studies on implementation of PPP in infrastructure projects shows that the owners have often contributed in the project investment (Abdel Aziz 2007a). For example the government authority in Canada Line, a
major transit project in Canada, paid 1.33 billion dollars to the contractor during the
correction of this 2.05 billion dollars project. Capital payment is almost mandatory for
transit projects for two main reasons 1) the ridership and the fares (and other incomes) in
these projects can not cover the construction as well as O&M costs, 2) most of transit
projects are extremely expensive and it would be very difficult for the private sector to
raise enough fund to start the project.

**Distinguishing Characteristics of Transit Projects**

The previous parts of this chapter defined different PDM options that a transit agency can
use for a new project. This part presents the major characteristics of the projects to which
these PDMs will be applied. The proposed DSS mainly concentrates of railroads (*e.g.*
light rail, commuter rail) and busways. These projects are classified as infrastructure
projects. They require a heavy investment and have significant impacts on the
communities adjacent to their corridors. Infrastructure projects are “capital intensive
[and] involve high initial sunk costs, with outputs that meet steady long term demand,
and site and use specific” (*Earl et al* 2003)

Transit projects are larger projects, usually in excess of $100 million. These projects
usually consist of at least two large contracts: civil and systems. The nature of these
contracts and the specialization required is such that usually two different contractors
deliver these contracts. This makes the coordination between these players of paramount
importance to project success.

The Federal Transit Administration (FTA) spends approximately $9 billion per year in
financial assistance to support public transportation across the country
This federal fund combined with other financial sources are invested in several new start projects and extension of operating fixed guideways and facilitate the commute for millions of riders in a year.

The costs of a transit infrastructure project can be divided into two categories: capital costs, and operating and maintenance (O&M) costs. “Capital costs are the start-up costs for the project, including the costs of guideway construction, stations, vehicles, and any system facilities necessary before the project can begin operation” (Los Angeles County Metropolitan Transportation Authority 2009). O&M costs include the costs associated with providing and maintaining a certain level of rail service. A large percentage of these costs are for salaries/wages and fringe benefits for drivers, mechanics, and administrative staff. Other items include fuel/lubricants, materials/supplies, utilities, and insurance (Colorado Department of Transportation 2008). The current FTA Standard Cost Categories consist of the following:

- Guideway
- Stations
- Support Facilities
- Sitework and Special Conditions
- Systems
- Right-of-Way, Land, Existing Improvements
- Vehicles
- Professional Services
- Contingency
Estimating operation and maintenance costs for a commuter rail involves two major steps: 1) development of operating plans and estimation of operating statistics, and 2) development of operating and maintenance cost models to estimate the operating and maintenance costs for the new service. A study conducted by Mid America Regional Council (MARC 2007) on I-70 Corridor Transit Project (a commuter rail extending from the Kansas City central business district and Crown Center area eastward to Odessa, Missouri) estimates the annual O&M costs of the project to be almost 7% of the total project capital costs. The O&M costs of this project are broken down to major elements (Table 2.2). The O&M estimates given in Table 2.2 also included a line item for contingency at 5% that has been removed for the purpose of this analysis.

**Table 2.2. O & M Cost Estimates for I-70 Corridor Transit project (34 miles)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Estimate per Mile (Year 2006 Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train operations</td>
<td>33,117</td>
</tr>
<tr>
<td>Equipment maintenance</td>
<td>120,882</td>
</tr>
<tr>
<td>Railroad access fees</td>
<td>29,205</td>
</tr>
<tr>
<td>Station maintenance &amp; operations</td>
<td>8,235</td>
</tr>
<tr>
<td>General and Administrative</td>
<td>53,264</td>
</tr>
<tr>
<td>Insurance</td>
<td>23,823</td>
</tr>
<tr>
<td>Total</td>
<td>268,526</td>
</tr>
</tbody>
</table>

Another study by Idaho Transportation Department on ValleyRide (a 23 miles commuter rail from Boise to the communities to the west, including Meridian, Nampa and
Caldwell) estimates $223,782 for O&M costs per mile in Year 2002 Dollars. The study assumes a 30 minute service and a 45 minutes service and the ratio of O&M costs to total project capital costs is between 4% and 5%.

An older study in Texas (Austin-San Antonio commuter rail study) estimates the O&M costs to be $175,000 per mile in 1998 Dollars. The project is a 111-mile commuter rail with 12 stations and can share tracks with Union Pacific Railroad. The ratio of O&M costs to total project capital costs is 4% for this commuter rail.

Another study on risk assessment of a commuter rail project (PBSJ 2004) for Tennessee Department of Transportation assumes a 2.6% increase rate in O&M costs for the years to come.

Assuming the same escalation rate for the past decade, O&M costs per mile found in the literature range from $240,000 to $290,000 in Year 2009 Dollars for commuter rail projects. These three commuter rails have different length, scope of work and location. However, the ratio of annual O&M costs to total project capital costs is between 4% and 7% for these projects.

The capital costs and O&M costs of a transit project are so high that project revenues (of any kind) do not cover them. Transit projects are not usually money makers and unlike some other infrastructure projects (e.g. toll roads or bridges) have not been successful in attracting private funds (USDOT 2007). Transit projects are generally funded by four sources: new tax revenues, grants from FTA, guarantees (bonds and alike) of subsidies from the state or municipalities, and the user fees. The farebox revenues in transit projects are sometimes as low as 15% of operating expenditures (Touran et al 1994).

Based on another study by Faruqi and Smith (1997), on average 42% of operating costs
are recovered from fare box revenue and 44% of the costs are compensated by the
government in the form of grants and subsidies. So it is difficult to apply public-private
partnership to the transit projects unless the government assumes major portions of
project revenue risks and defines the concession and concession period in a way that
private financing becomes viable.

Another distinguishing characteristic of transit is that typical projects can be multi-modal
as well as incorporating a significant degree of architectural features that extend the
project outside the scope of a normal engineered project and demand the involvement of
design professionals from architecture, landscape architecture and interior design. The
integration of “vertical” construction features such as parking structures and transit
stations with the “horizontal” construction features such as track bed, bridges, and
roadway elements creates a need for a comprehensive set of both design and construction
services that is not normally found in transportation projects. In addition, the need for
transit agencies to integrate their facilities with other modes of transportation demands
another comprehensive set of both design and construction service providers and requires
a more flexible approach to design and construction than single mode transportation
projects.

Additionally in the case of commuter rail projects, a freight line may be in the mix where
the owner will have to share the line with temporal separation or track separation. This
makes coordination with the railroad company owning the freight line extremely
important. Reaching agreements with the railroad company and clarifying the details of
the work and responsibilities of various parties cannot be overemphasized (TCRP 2009).
The railroad company usually wants to do the track work with its own forces on a cost
reimbursable basis and this puts all the risk on the owner. This also increases the constructor’s risk because its work may be impacted by the railroad. This makes early involvement of the construction contractor very important to project success. Also, the railroad company tends to do the work at its own pace while considering project milestones; as a general rule, the agency does not enjoy the same degree of control that it exerts over the constructor with the railroad company.

Finally, federal support for transit projects, often crucial for bringing the project into reality, depends on specific steps not similar to other transportation projects. The Federal Transit Administration (FTA) plays an important role in this process. Various transit agencies compete for federal dollars by preparing specific reports for the FTA. Depending on the rating that a project receives, it may be permitted to move into the next development stage. The burden is on the owner agency to ensure that the project remains viable and meets the federal requirements.

**Conclusion**

This chapter defined the main PDM options available to transit agencies. It also briefly discussed the advantages and disadvantages of each of those PDMs. Transit projects have been constructed using most of the delivery methods available in construction industry but despite its use in other countries (e.g. the UK), there is no public transit project executed under PPP in the United States. The USDOT report to Congress on PPP in 2007 shows that no transit project in the US has been done with the financial partnership of private sector (except for Las Vegas monorail which has had difficulties in safety and operation and also was not even initiated by a need from the government). Application of
alternative delivery methods (DB and CMR) is also limited and not every state can apply them to its project.

Transit projects have a number of unique characteristics that affect the choice of delivery method. Their size, complexity, dimensions, length of schedule, construction and operational risks, and revenue generation problems are some of the major defining points for transit projects. This part of the dissertation explained these characteristics and related them to the issues that may affect the decision makers while selecting a project delivery method for a transit project.
Chapter 3. Decision Support System for PDM Selection

Introduction

Project delivery method selection happens early in the project life cycle but it affects the project schedule, cost, and quality control. It also affects the relations between the parties involved in the project. Nevertheless, project delivery method selection is not inherently different from many other decisions an owner or executive director of a company would make, so similar decision support systems (DSS) can be applied to delivery method selection.

A DSS assists the decision maker by providing sufficient relevant knowledge and a framework for decision. A DSS can be as simple as a list of critical factors to be considered or as complicated as a complex software package. “Decision Support Systems comprise a class of information systems that draws on transaction processing systems and interacts with the other parts of the overall information systems to support the decision making activities of managers and other knowledge workers in organizations.” (Power 2002)

Although using a DSS may have its own risks and limitations, the user may benefit from an appropriate DSS because of the improvements it makes in the following items:

- Individual productivity
- Decision quality and speed of problem solving
- Decision making skills
• Interpersonal communications

• Organizational control (Power 2002).

The DSS mainly emerged after the evolution of Management Information Systems (MIS) in late 1960s and have always been influenced by the changes in data processing. Power (2002) identifies three characteristics for decision support systems:

“1- DSS are designed to specifically facilitate decision processes,

2- DSS should support rather than automate decision making, and

3- DSS should be able to respond quickly to the changing needs of decision makers.”

DSS can be divided into five categories: data-driven DSS, model-driven DSS, knowledge-driven DSS, document-driven DSS, and communications-driven DSS. Building a new DSS entails an improvement and change in one of the following: 1) the user interface, 2) the database, 3) the model and analytical tool, and 4) the DSS architecture and network (Power 2002).

DSS can be found in different forms and used in various ways. They can differ in format, scope, and applications. Some work better for problems under certainty while another group of DSS are developed for problems under uncertainty. In the same vein some DSS are for problems with multiple objectives and some are for problems with a single objective. Owners have a number of objectives in terms of cost, schedule, quality, level of control when deciding on project delivery method, i.e. PDM selection is a problem with multiple objectives.
One way of dealing with the issue of PDM selection is to consider the uncertainty and use probability distributions for modeling utility functions which will make the decision making more complex. The precision of modeling should be weighed against its practicality. The inconsistency in inputs provided by decision makers, lack of information at the time the PDM is chosen, and the distinguishable differences in the performance of different delivery methods undermines the importance of precision in selection of a complex decision support system that includes uncertainty. In other words, the selection process becomes much simpler (at little risk) by regarding the outcomes as certain, when the outcomes of each available course of action are almost certain (Oyetunji 2000; LaValle 1978). So the performance of delivery methods with respect to each measurable factor is considered to be certain. Even when the effect of a PDM is not clear, the owner assumes a certain level of impact by each PDM, therefore the problem of PDM selection is treated as a problem under certainty. For example, the overlap between the design and construction phase in a design-build method is considered to have a certain positive impact on schedule shortening.

The DSS developed in this dissertation is multi-objective and knowledge-driven. It will “suggest and recommend actions to managers” and should be applied by people with expertise and knowledge of the particular domain (Power 2002). The DSS is also function-specific because it is specifically developed for transit agencies and is not an “off the shelf” decision support system.

Available Decision Support Systems for PDM Selection

Availability of several delivery methods each with its own abilities has raised a demand in the construction industry for reliable and consistent decision support systems that can
help the owners in selecting a suitable project delivery method. Selection of the appropriate project delivery method is a complex decision-making process. It is a multi-criteria decision and should be made as early in the design phase as possible; preferably during the project scoping process and certainly before the final construction cost estimates are ready. Suitability of a project for PPP should be studied even earlier than other delivery methods mainly because it drastically changes the course of action in the project financing and procurement. The selection will occur when the owner still has little information about the outcome of the project and the project plans are not detailed enough to be reliable grounds for judgment about the project. This environment clearly shows the importance and necessity of developing a framework for decision-making which is simple, comprehensive, rational, and objective.

The literature to date illustrates that experts have developed several ideas and decision support systems for project delivery method selection. They have developed a list of criteria and several decision making frameworks (Gordon 1994; Konchar et al 1998; Al-Hazmi et al 2000; Al Khali 2002; Debella et al 2006; Mahdi et al 2005; Ibbs et al 2003; Oyetunji et al 2006; Garvin 2003; Mafakheri et al 2007; TCRP 2009; NCHRP 2009). They have mainly considered DBB, DB and CMR. Others like Ababtain et al (2003) have considered PPP and have defined a multi-criteria decision making system to be used for toll roads. Factors and issues considered by these authors are either quantifiable like cost growth, schedule delay, and number of claims, or qualititative like owner’s control over the project, sustainability, and staff capability.

One can roughly divide the relevant literature into two groups: (1) the papers and reports that compare the delivery methods based on the observed performance measurements,
collected from a group of projects, and (2) the papers and reports that propose a framework for decision making given a set of relevant criteria. The distinguishing factors introduced by first group overlap or complete the set of criteria found in the second group of papers.

One of the best examples for the first group is a paper by Konchar et al (1998) in which a set of criteria is defined for a performance comparison of different delivery methods (i.e. DB, DBB and CMR) in 351 projects. These criteria are mostly objective and measurable, such as cost growth, construction speed, and schedule growth. Some criteria are also defined to incorporate the quality performance of the delivery methods, like difficulty of facility start-up, number and magnitude of call backs, and operation and maintenance costs. The main finding of the paper is the positive effect of DB on project schedule and cost. However, when the authors divide the projects into six different groups (such as light industrial, complex office, heavy industrial, etc.) in order to get a more robust result about the trends in each group, the paper does not have enough data to distinguish between the performances of different delivery methods in transit projects. Two studies have compared DB and DBB performance in the federal building sector. The first has compared 54 DBB projects to 34 DB projects and discovered that DB projects had 16.4% less cost growth and 19.0% less time growth than similar DBB projects (Gransberg et al 2003). Another study looked at 110 Navy projects and found that DB projects again performed better, with 18.0% less cost growth and 60.0% less time growth (Allen et al 2002). Additionally, a recent NCHRP study of best value contracting (Scott et al 2006) furnished direct comparison of transportation project performance for various delivery methods. While this study did not consider CMR projects, it did include DBB projects
awarded on a best value basis which is similar to the CMR delivery method. It found that DB projects had 4.7% less cost growth and 9.3% less time growth. Best value projects had 2.0% less cost growth and 18.5% less time growth compared to traditional DBB projects. Others such as Debella et al (2006) and Ibbs et al (2003) have used a methodology similar to Konchar’s, but they have narrowed down the scope of their research either to special kind of projects or fewer performance measures.

PPP delivery method does not have a long history and certainly there is no transit PPP project in the United States in operation phase. The number of PPP projects around the globe is not enough either for a statistically robust conclusion and that is one of the reasons for not finding enough papers and reports in the relevant literature (some reports focusing on UK and Australia are referred to in the PPP benefits section of this dissertation). A USDOT report to Congress (2007) portrays some of the PPP benefits in measurable terms such as schedule shortening, cost savings as well as other qualitative factors such as operating efficiency and integration of project development and delivery. In addition, some authors have expanded the discussion on PPP procurement phase and have provided guidelines for private partner selection. Ababutain et al (2003) have defined a set of criteria including promoter’s qualifications, project evaluation, financial feasibility, implementation requirements, and socioeconomic effects in an AHP framework for the selection of the best BOT proposal for a toll road. Zhang (2005) has put together a long list of criteria categorized in four groups of financial, managerial, safety, and technical for the private partner selection. He has extended his discussion in another paper with a focus on best value procurement method (Zhang 2006c).
The second group of papers and reports have focused on the decision making process. These sources propose mechanisms for decision making and define the necessary criteria and frameworks so that the most important project parameters are defined and used in the decision making method. Most of the developers of these systems strive to create frameworks that are simple, rational, and comprehensive. They range from basic flow chart methods (Gordon 1994) to more sophisticated processes based on methodologies such as multiple linear regression (Molenaar 1998), the Analytic Hierarchy Process (AHP) (Al Khalil 2002; Ababtain et al 2003; Mahdi et al 2005; Mafakheri et al 2007), or Simple Multi Attribute Rating Technique with Swing weights (SMARTS) (Oyetunji and Anderson 2006).

Gordon (1994) created a procurement method selection model that uses an objective framework (i.e. flowchart) for selecting the best contracting method. Within the flowchart are a number of drivers (motives) that direct the owner’s attention to the most important issues in delivery method selection. The delivery methods considered by Gordon are general contractor, construction manager, multiple primes, design-build, turnkey, and build-operate-transfer. Gordon has not limited his proposed approach to PDM selection to certain types of projects. This has helped him develop a big picture of PDM selection; however, distinguishing characteristics of different projects (size, third party agreement, laws, etc.) are neglected in his approach.

Skitmore and Marsden (1988) presented a multi-attribute analysis technique and a discriminant method for selecting delivery methods. The multi-attribute method evaluates the suitability of a delivery method with respect to a client’s priority criteria. American Council of Engineering Companies (ACEC 2005) published a manual for the owners and
suggested that they should choose the most appropriate delivery method based on the project goals and objectives. The broad categories of project goals in this approach were quality, cost control, design expertise, schedule, specific product or outcome, risk, legal requirements, political direction, safety and security, and sustainability. The manual did not provide the owners with any decision tool and instead recommended the use of professionals to properly “match” the project with an optimal delivery method. Oyetunji and Anderson (2006) used a Simple Multi-attribute Rating Technique with Swing Weight (SMARTS) approach for delivery selection for projects. They considered 12 project delivery alternatives which were basically CMR and several variations of DBB and DB. The approach utilized a matrix that had 20 factors each with pre-determined weights. Examples of these factors included control cost growth, facilitate early cost estimate, control time growth, ease of change incorporation, protect confidentiality, and capitalizing on well-defined scope. The effectiveness of each project delivery alternative with respect to each of these 20 factors was given to the owners by a predetermined number from 0 to 100 and the owner should rate these criteria, give them a weight based on their importance and go through the required calculation that give a single rate to each delivery method. The delivery method with the highest rank should be chosen for the project. The method was developed for Construction Industry Institute (CII) and the cases in this method were mainly building projects. The method mixes delivery methods with contracting and payment methods. At the same time it does not consider PPP among delivery methods.

Al-Hazmi and McCoffer (2000) proposed a project procurement system selection model (PPSSM) that combined AHP and some value engineering methods. It consisted of four
layers and 10 groups of criteria like time, cost, market attributes, regulations, etc and studied 13 procurement systems. The proposed model first used some filters like feasibility ranking and weighted evaluation and then used AHP as a screening layer to find the final answer. The authors have also presented the results of the model application in Saudi Arabia where nearly half of the respondents had chosen design-build as the most appropriate delivery method. A major shortcoming of this PDM selection model is mixing contracting methods with delivery methods. For example they compare “negotiation method” with “construction management” while they are essentially incomparable.

Al Khalil (2002) believed that Analytic Hierarchy Process (AHP) was a suitable decision tool for the owners to select a project delivery method because of its ability to incorporate “tangible and intangible factors” and the possibility of breaking down the problem into AHP hierarchies. Al Khalil chose DBB, DB and CMA (Construction Manager Agency) as the owner’s options and defined 12 influencing factors and categorized them into three main groups of project characteristics, owner’s needs, and owner’s preferences. Some of the factors considered by Al Khalil were schedule, price, complexity, design control, and constructability. The fixed weights provided in the AHP model are less reliable in this research because the projects under consideration are not limited to a special kind (building, transit, airport, etc.). At the same time consideration of CMA as a delivery method is not correct, as the CMA is not ultimately responsible for delivering the project.

In the same vein, Mahdi et al (2005) suggested an Analytic Hierarchy Process (AHP) for decision making and defined a set of factors for the AHP model. The delivery methods considered were DBB, DB, CMR and CMA (Construction Manager Agency). They
defined a list of factors such as cost savings, time reduction, risk allocation, conflict of interest, and allowing of competitive bidding and then divided these pertinent factors into seven groups: owner characteristics, project characteristics, design characteristics, regulatory issues, contractor characteristics, risk, and claims/disputes. The AHP model considers CMA as a delivery method while it is essentially a project management method rather than a delivery method. It does not include PPP as a delivery method and does not limit the scope of projects so the accuracy of the fixed weights provided becomes less reliable. It is reasonable to expect that these weights would be a function of project type.

Mafakheri et al (2007) preferred AHP over other methods of decision making and developed a list of criteria to be used by the owners when evaluating the delivery methods. In their paper they listed 13 factors such as cost, time, financial guarantee and even culture. They used these factors to evaluate DBB, DB, CM/GC (Construction Manager/General Contractor), and CM/PM (Construction Manager/Project Manager). In their paper, they have focused on the uncertainty in decision making and have attempted to address it by providing a range of values for weights of the factors in AHP. The method lacks the inclusion of financial aspects and does not include PPP.

National Cooperative Highway Research Program has conducted a survey of DOTs in the US and has published a synthesis (NCHRP 2009) in which the public sector decision making for PPP method is studied. The synthesis adopts the USDOT definition of PPP (USDOT 2004) and concludes that four major factors should be considered in the evaluation of PPP option: 1) valuation of alternative approaches, 2) appropriate risk transfer, 3) transparency and public participation, and 4) complexity of the transactions. The report recommends the use of Value for Money test as a well-known method for the
valuation of alternative approaches but does not give case studies or detailed procedures.
The synthesis is also limited to highway projects and does not cover other types of infrastructure projects or other project delivery methods.

In summary, the existing body of knowledge in this area, along with specific information collected on transit projects, provides a solid foundation for developing a new selection system for the transit projects. The proposed methods in the literature introduce a list of criteria affecting the decision and are usually based on well-known approaches such as weighted matrix (Oyetunji et al. 2006) or AHP (Mahdi et al. 2005; Ababutain et al., 2003). However, the literature search shows that there has been no complete decision making method in which project finance is also taken into consideration and PPP method is compared with other delivery methods (e.g. DBB, DB, and CMR). Inherent differences between PPP and more conventional methods such as DBB or CMR make it more important to have a comprehensive evaluation framework that includes financial factors as well as schedule, cost, risk and similar pertinent issues. Inclusion of PPP in the framework has become more important recently as the governments are more inclined towards delegating their traditional roles in building infrastructures to the private sector.

This dissertation will develop a more comprehensive methodology which is a combination of qualitative and quantitative approaches. It will similarly define a list of pertinent issues that affect the choice of delivery method in the context of transit industry. This list includes parameters such as cost growth, schedule compression, staff capabilities, construction claims, and risk management. These parameters will be used in an analytical approach and a weighted matrix (or AHP depending on the desire of the user of the selection system). The concept of Net Present Value (NPV) and risk allocation
will be used in the quantitative part to compare PPP and other delivery methods at the first stage and then compare DBB, DB and CMR in the second stage. The framework will be explained in the following parts of this chapter. The proposed system includes the qualitative parameters as well as quantitative parameters and is developed in a way that matches the decision making process in owners’ organization. In other words, it first studies the feasibility of PPP for the project and then goes to the next step in which the comparison will be among DBB, DB, and CMR.

Critical Factors

As mentioned in Chapter 2, PPP can be separated from the rest of the delivery methods because of the inclusion of project finance. Accordingly, the critical factors to be considered while evaluating PPP should be different from those considered for other delivery methods. The owner’s decision on PPP delivery method is partly dependent on its desire to absorb private funds into the project, so financial aspects of project and its ability to generate revenue become extremely important. Other delivery methods, i.e. DBB, DB, and CMR, do not necessarily have a financial element in their structure and are inherently different from PPP. In other words, the owners should first decide whether or not to use PPP. This would help the owner have better estimates of how much it should spend for the project capital costs. If the project is found to be a candidate for PPP, the private sector would partially pay for the capital costs.

If the answer is negative, the second decision would be to select a conventional project delivery method (DBB, DB, or CMR). The parameters and factors considered in each of these two decision points have some overlaps but are not the same. For example, the concept of NPV can be used in both of the two decision points but financial attractiveness
of the project does not have much to offer when it comes to the selection among DBB, DB, and CMR. In order to evaluate the appropriateness of PPP, one should take into account the financial aspects of risk transfer, attractiveness of project for private sector investment, etc. These factors are either not considered when conventional delivery methods are evaluated or have minimal effects on the decision.

The proposed decision support system considers the aforementioned sequence of decision and also the distinction between the critical factors affecting the choice of PPP and the pertinent issues affecting the appropriateness of other delivery methods including DBB, DB, and CMR.

Based on the literature review, real projects in other countries, and interviews a list of factors is suggested here to be considered for PPP evaluation. The first group that affects the choice of PPP consists of: project size, investment environment, project viability, private sector capacity, risk allocation, competency of public agency, potentials for improving Value for Money (VfM), development of performance specification, and value for money. Value for Money is defined by HM Treasury (2006) as “The optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user’s requirements.” This factor which encompasses all the relevant financial calculations of PPP has the highest influence on decision making, however, it should be considered and its calculations should be done only after the other factors show the feasibility and appropriateness of PPP for the project under study. A complete discussion on this issue is carried out in Chapter 7.
The second group of factors that should be considered when comparing the conventional delivery methods (DBB, DB, and CMR) can be categorized into five groups:

Project-level issues, agency-level issues, public policy/regulatory issues, life cycle issues, and other issues. Project-related parameters are those parameters that pertain to the duration, estimated cost, quality level, project risks, limits on schedule growth, and project complexity. Agency-related parameters are about the owner agency such as experience and competence of agency’s employees, flexibility needs in construction phase, level of risk assumption, importance of preconstruction services, and quality level expectations. Public policy and regulatory parameters mainly cover the legal and contracting issues, for example, the authority of using a delivery method in a state, the level of competition in the market, and various permits needed for the project. Life-cycle issues cover the costs of maintaining and decommissioning the facility as well as the ability to minimize energy and environmental effects of the project. Other issues such as construction claims and adversarial relationship were categorized in a separate group.

The factors of each of the aforementioned five groups will be explained in details in Chapter 4 (Analytical Delivery Decision Approach).

**Introduction of the Proposed Decision Support System**

The proposed decision support system (DSS) is introduced in this part. The framework and the flow of the decision as well as major elements of the proposed DSS are introduced in this chapter of the dissertation but the details of decision making in each tier are explicitly explained in the following chapters.
The flowchart of the proposed DSS is shown in Figures 3.1 and 3.2. Each box in this flowchart represent an action in the decision making process; some of the actions may require more time and effort than others. Nevertheless, all of them are explained here. More details will be provided for the three tiers and decision on PPP in the following chapters.

To better illustrate the correlation between the activities of decision support system the flowchart of decision is divided to four major subdivisions: 1) Preliminary evaluation of PPP, 2) Conventional PDM selection, 3) PSC selection, and 4) PPP final evaluation and project award (Figure 3.1 and Figure 3.2). Preliminary evaluation of PPP consists of a number of qualitative factors regarding the project, the owner, market and finance. Conventional PDM selection has 3 tiers which are 1) pro/con analysis, 2) multi-criteria decision tools, and 3) risk-based approach. PSC selection uses the same 3 tiers to select a PDM from DBB, DB, and CMR. PPP final evaluation receives the output of PSC selection and applies the NPV calculations in PSC-PPP comparison to come up with the PDM that makes more value for the money invested in the project.
In the following section, each numbered box of the flowchart of Fig. 3.2 is explained.

1) Study the project and its environment, collect data on the performance of similar projects, estimate project costs and project schedule, and analyze the legal and financial restraints. Here the owner develops its knowledge of the delivery methods such as the results of applying different PDMs to similar transit projects. The data collected in this phase will help the owner in its decision later in the process.
Figure 3.2. Decision Support System for PDM Selection Flowchart
2) Here the evaluation of PPP option should be done in the first step which is pre-advertisement evaluation (Please refer to Chapter 7 - Decision on PPP, before advertisement). The factors to be considered are illustrated in Figure 3.3.

Figure 3.3. Influential Factors on the Evaluation of PPP Method before Project Advertisement

3) The set of advantages and disadvantages for DBB, DB, and CMR from the owner’s viewpoint should be reviewed in this part of the decision making (Please refer to Chapter 4 - Analytical Delivery Decision Approach). Here the owner analyzes the conventional delivery methods based on a set of 24 pertinent issues introduced in Chapter 4.

4) Tier 1 which is the analytical approach should be followed in this part. Figure 3.4 illustrates the flowchart of the decision in Tier 1 but please refer to Chapter 4 - Analytical Delivery Decision Approach for the details of the approach.
Figure 3.4. Tier 1 Flowchart: An Analytical Approach for Conventional PDM Selection

(adopted from TCRP 2009)

5) Following the analytical approach, the owner should decide whether or not a PDM can be selected based on the evaluation of 24 pertinent issues.

6) Tier 2 which is the multi-criteria decision approach should be followed in this part. Here the decision making team can decide whether to use weighted matrix or AHP as the decision making tool. Figure 3.5 shows the steps for the weighted matrix approach. The
details of AHP and weighted matrix are provided in Chapter 5 (Multi-Criteria Decision Approach).

Figure 3.5. Tier 2 Flowchart: Weighted Matrix Approach for Conventional PDM Selection

(adopted from TCRP 2009)

7) Based on the steps of Tier 2 and the results achieved, the owner should decide whether or not an appropriate PDM can be selected. If at the end of the two tiers still more than one alternative remains viable, the owner is recommended to go to Tier 3, which is a risk-based approach.
8) Tier 3 of the conventional PDM selection is a risk-based approach. In this tier the owner should study the effect of available PDMs on risk allocation and then risk mitigation. This tier will concentrate on how to quantify the effects and probability of risk factors in each PDM. Chapter 6 (Risk Based Approach) explains the qualitative (risk allocation matrix) and quantitative approach to PDM selection based on project characteristics.

9) After applying the three tiers, here the owner needs to review the results of each and select the most appropriate PDM for the project. The owner is expected to evaluate the results and assure that they are reasonable, robust and reliable.

10) The results of each tier and the decision making process followed by the owner should be briefly explained in a report. This report increases the transparency of the decision and makes it more defensible. The report should include the project goals and the steps followed for selecting the PDM.

11) Many owners would consider PPP as a means of starting new projects without facing the excessive initial costs. These owners should always consider the present value of project pay-back to the private sector during its useful life and check if it is worthwhile for the public. At the same time, it should be mentioned that there are owners who cannot start a new project unless they can find new sources of fund. Budget restrictions, increasing deficit, and limits on issuing bonds are some of the reasons why the owners may be forced to use the PPP. How an owner would approach PPP while facing these limits is discussed in this part.

12) This is similar to Step 3 of the flowchart.
13) This is similar to Step 4 of the flowchart.

14) This is similar to Step 5 of the flowchart.

15) This is similar to Step 6 of the flowchart.

16) This is similar to Step 7 of the flowchart.

17) This is similar to Step 8 of the flowchart.

18) This is similar to Step 9 of the flowchart.

19) This is similar to Step 10 of the flowchart.

20) PSC calculation will be explained in this part. The Public Sector Comparator (PSC) is a benchmark used to determine whether or not the private proposals offer better value for money to the public. The PDM considered for this calculation should be the one chosen in Step 19. Please refer to Chapter 7 (Decision on PPP) for more details.

21) How to define the project scope and its performance specification is extremely important in the success of PPP. The owner is expected to work on performance specifications and develop enough documents and details of the project that the private sector entities can grasp the scope of the project and the owner’s expectation so that they can submit their proposals for the project.

22) “Value for Money” is a general term that refers to the methodology of evaluating the PPP both in qualitative and quantitative ways. This analysis is performed to find whether the PPP method is worth the owner’s money spent in it or not. Pre-advertisement evaluations mainly focus on qualitative factors (Figure 3.3) and the quantitative
the comparison between PPP bids and calculated PSC is done only after the project advertisement and receipt of private sector proposals (Figure 3.6). PPP should not be selected, if the result of this comparison shows that the PPP method is not adding value to the money spent for the project (Chapter 7 – Decision on PPP).

![Figure 3.6. The Value for Money (VfM) Test Flowchart for PPP Evaluation](image)

23) If the result of the VfM test in Step 22 shows that the PPP method is not the most appropriate option for the project, the owner should move on and carry out the project with the conventional method (DBB, DB, or CMR) already selected in Step 19.

24) This is similar to Step 21 of the flowchart.

25) This is similar to Step 22 of the flowchart.

26) The results of the test show that PPP is the most appropriate delivery method and should be selected for the project.

27) Considering the fact that other PDMs rather than PPP do not bring in private funds, if the PPP method cannot be implemented according to the results of the evaluations and comparisons, the owner of the project would be left with few options. In this case the
project should be canceled, or the project scope should be redefined or new sources of governmental funds or guarantees must be found.

**Conclusion**

The available decision support systems in the literature were reviewed in this chapter. Considering the characteristics of transit projects, nature of decision making in transit industry, state of practice in PDM selection, and available decision tools the framework of a DSS was introduced in this chapter. This framework sets the stage for the following chapters. Each of the major tasks in the framework will be explained in the rest of the dissertation. One major outcome of the literature review was a set of critical factors to be considered when comparing the PDM options. These factors will be introduced in Chapter 4.
Chapter 4. Analytical Delivery Decision Approach (Tier 1)

Introduction

A primary step in selecting a project delivery method for an owner of a transit project is to decide on applicability of public-private partnership. If the private sector participation in financing the project is not anticipated, the project is not suitable for such a partnership or for any particular reason the PPP cannot be applied, the owner is expected to select one of the conventional project delivery methods (DBB, DB, and CMR) using a consistent and systematic approach. A simple way of making a decision would be a holistic approach in which the best option is selected from the available options without any further analysis. This arbitrary decision making is not based on a systematic approach and is not supported by a documented method. A more systematic method would be an advantage/disadvantage analysis which is introduced in this chapter. An advantage/disadvantage analysis includes a set of critical issues that cover different aspects of decision and helps the decision makers better understand their choices. In order to perform the analysis, a set of critical factors should be developed and a structured method should be applied so that the result is reliable and defensible. This chapter first explains the importance of defining project goals in the PDM selection and ultimately in the success of project. It then introduces a set of 24 factors that affect the PDM decision in a transit project. This set of factors was first developed during the TCRP 131 research project (TCRP 2009) and was tested for its comprehensiveness by several transit experts. A comprehensive analysis of advantages and disadvantages of each project delivery method with respect to those 24 factors is also presented in this chapter. At the end, a
procedure is introduced so that the owner can utilize the advantage/disadvantage analysis to identify a decision. A legal search on state codes affecting the authority of transit agencies throughout the US is also presented as a part of this chapter.

**Project Goals and Success Factors: Owner’s Perspective**

Projects differ in their scope of work and their major elements (*e.g.* people involved, physical project characteristics, project duration, project budget). These distinguishing parameters affect the project delivery method selection simply because the delivery methods are the frameworks in which the involved parties perform their roles towards the project success. Agencies should choose the most appropriate delivery method on the basis of the project requirements and the opportunities that each delivery method can provide for them. The first step would be the creation of a project description. The objective of creating a project description is to explain the project in sufficient details to document the project delivery decision. The project description should be concise and also comprehensive. It should include the necessary information about the project and address all aspects of the project that may be influenced by the selected delivery method. It also serves to communicate the decision to interested stakeholders and to justify the decision if issues arise years later as the project is completed. The TCRP Guidebook (2009) suggests the following checklist of the important project characteristics that should be covered in the project description.

**Project Description**

- Project Name
- Location
- Mode of Transportation
- Estimated Budget
Understanding and communicating a concise set of project goals is perhaps the most important element in selecting an appropriate project delivery method. The definition of project goals is a key success factor in not only the project delivery decision, but also the development of procurement documents and the administration of a project. The project will have technical goals that must be met (e.g. meeting anticipated ridership, meeting design standards, meeting safety standards) and will also have performance goals regarding time, cost, quality, maintainability, and sustainability. It is the performance goals that typically drive the project delivery decision.

At project inception, the agency must identify the various performance aspects of the project to meet its requirements. Generally, these will fall into the categories of cost, schedule, and quality as defined by the technical design specifications. Of these three factors, the project will normally have one which is the most important for this project’s ultimate success – the preeminent factor. This preeminent factor is the factor for which
the agency will sacrifice pieces of the other two goals to achieve the goal relating to this factor. For example, consider the University Line that was constructed by the Utah Transit Agency in Salt Lake City, Utah. While the Utah Transit Agency obviously had a fixed budget and certain standards to maintain with regard to quality, schedule was the preeminent factor because the project had to be finished prior to the start of the 2002 Winter Olympics. This was a primary reason why the Utah Transit Agency selected DB project delivery. In this case, the owner could not complete the necessary work using the traditional process in time to meet the deadline (TCRP 2009).

A clear and concise definition of project goals not only assists with selecting an appropriate project delivery method, but also provides a clear measure for project success and clear direction for the project manager or design-builder to complete the project. These project goals set the stage for decision makers throughout the project life cycle and show them the priorities while analyzing different alternatives. Project goals provide input for choosing the procurement method, risk allocation strategies, contracting, monitoring progress and at the end, evaluating the project success.

Define project goals in terms of performance categories can be helpful. Time, cost, quality, and suitability are common categories. Choosing the goals that apply to a specific project is a first critical step in an agency’s selection of delivery method. The second, and equally important step, is the ranking of the goals.

As previously stated, understanding and communicating a concise set of project goals is perhaps the most important element in selecting an appropriate project delivery method. Agencies should take the time to identify project goals and achieve consensus on their
relative importance. This time will be well spent as it will make the project delivery
decision clearer. It will also help to define and communicate overall project success,
thereby aligning the designers and constructors with the agency’s project performance
measurement factors.

**Legal Restrictions on Alternative Delivery Methods**

In general, a construction project starts with a need and/or idea in the owner’s
organization. The owner needs to hire professionals for design, management and
construction of the project if there is not enough expertise in-house. Contractual relations,
contemporary laws and regulations, owner’s perception of risks, awarding mechanism
and the method of payment all contribute to project delivery system selection. Based on
Public Law 92-582 (Brooks Act) passed in 1972 and similar laws passed by individual
states (Little Brooks Acts), public projects in the United States should be designed by the
quality-based selected designers. On the other hand the construction of the project must
be awarded to the lowest responsible, responsive bidder. The combination of these two
has led the public agencies towards the adoption of Design-Bid-Build (DBB) delivery
system. This method was overwhelmingly dominant in transportation projects until 1996
when the Federal Acquisition Reform Act authorizing the use of Design-Build (DB) for
federal projects was passed. After that the Transportation Equity Act for the 21st Century
(TEA-21) allowed the states Department of Transportation (DOTs) to award a DB
contract if the state code lets them do so (Molenaar et al. 1998). Subsequent to the
successful experience of using DB in several projects a number of states passed
legislations and codes to allow alternative project delivery systems including Design-

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3 This part of the dissertation is published as a paper in the *Journal of Professional Issues in Engineering Education and Practice, ASCE.*
Build, Construction Management at Risk (CMR) and Public-Private-Partnership (PPP) in transportation projects.

The laws and regulations of the state where the transportation project is being considered play an important role in the choice of project delivery system. In many states, simply there is still no choice other than the traditional design-bid-build approach. The trend however, is a constant change of laws to allow more flexibility for choosing the contractor. This part of the dissertation is based on a review of the legislative codes and statutes in all the 50 states (state codes). It shows which states have approved the use of alternative project delivery systems, namely Design-Build, Construction Management at Risk, and Public-Private-Partnership in the transportation projects, i.e. highways, roads, commuter rails and light rails. The search process is thoroughly explained and the difficulties are highlighted for the readers who may want to follow the study in other construction sectors. The trend of authorizing each alternative delivery system is also studied. The results of the search show that every state has given certain level of authority to the DOT. This spectrum starts with the states where the DOT can use an alternative delivery system in a project without any limitations or any need for extra approval (fully authorized). Some states require extra approvals from entities outside the DOT for the use of an alternative delivery system (authorized but needs extra approvals). There are some other states that appreciate the abilities of alternative delivery systems and authorize their use in transportation projects but put some limits on their use and/or have defined a pilot program for that purpose (authorized for a pilot program with some limitations such as limiting the number of projects authorized in the pilot program or the mode of transportation for which the alternative delivery system is authorized). The rest of the
states have not yet authorized the use of alternative delivery methods in transportation projects (not authorized). As an outcome of this observation, all the states are categorized in these four distinguishable groups based on the level of authorization as follows:

1) fully authorized
2) authorized but needs extra approvals
3) authorized for a pilot program and/or with some limitations
4) not authorized

This classification is exhaustive and covers all the possible variations in legal matters dealing with delivery methods. This categorization of states is important in view of the myriad of laws that put various limitations on the use of alternative project delivery methods. The results are explained in detail and illustrated in tables and maps. These codes were largely checked in December 2006 using LexisNexis search engine. One important issue in this type of research is the realization that state codes in this area are constantly changing. States have made significant changes to their laws in the past 10 years with regards to alternative project delivery systems. Wording of statutes are different in state codes and the scope of the authorization is sometimes not clear; so in order to make sure that nothing is missed, several key words were used and after finding statutes, they were double checked to make sure that the scope of the authorization includes the transportation projects. The keywords are listed below:

The focus of this research is transportation projects. Some states permit an alternative delivery system to be used in some other types of projects but not transportation projects. For example, Florida allows using CMR for educational facilities, but no statute permits this application for DOT projects and because of that, Florida is considered a “not authorized” state. Another point is that some states authorize an alternative delivery system rather than the traditional one for some special transportation projects. In other words, there is no statute authorizing DOT for using alternative delivery method in general, but some projects are permitted to be done under DB, CMR or PPP contracts. These states are still considered “not authorized” states.

In order to increase the validity of the findings, the results were sent to several industry experts and researchers and their feedback was incorporated into this part of the dissertation. This section should not be construed as legal advice or a legal reference for decision-making regarding alternative project delivery systems.

Design-Build

Based on the current laws, 17 states have fully authorized DOTs to apply DB in their projects. For example, in Colorado, C.R.S. § 43-1-1401 says that the department of transportation is authorized to enter into design-build contracts and to use an adjusted score design-build selection and procurement process for particular transportation projects regardless of the minimum or maximum cost of such projects.
Two states need extra approval from an entity outside of the DOT, like the house or senate. As an example, in Louisiana, La. R.S. 48:250.2-4 mentions that the secretary of the DOT, with approval of the House and Senate Transportation, Highways and Public Works Committees, may use the design-build method on any transportation infrastructure project in an area impacted by a hurricane.

In 18 states, lawmakers have decided to define a pilot program for using DB or have put some limitations (either the number or cost of projects in a period of time) on using this delivery system. For example, in Ohio (ORC Ann. 5517.011) there is a limit of $250 million for the total dollar value of the contracts made under DB delivery system. Another example is the state of Montana (Mont. Code Anno., § 60-2-135) where the DOT is authorized to establish and implement a design-build contracting pilot program (2003-2008) for highway construction.

Based on the aforementioned data, 37 states use DB in their transportation projects while 13 state DOTs still do not have the authority to do so. The states are categorized in table 4.1.
Table 4.1. Legal Status of States regarding the Use of Design-Build in Transportation Projects

<table>
<thead>
<tr>
<th>Fully authorized</th>
<th>Authorized but needs extra approvals</th>
<th>Authorized for a pilot program and/or with some limitations</th>
<th>Not authorized</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK, AZ, AR, CO, DE, FL, HI, ID, IL, IN, KY, ME, MD, NJ, SD, TN, VA</td>
<td>LA, OR</td>
<td>CA, GA, MA, MN, MS, MO, MT, NV, NH, NM, NC, OH, SC, TX, UT, WA, WV, WI</td>
<td>AL, CT, IA, KS, MI, NE, NY, ND, OK, PA, RI, VT, WY</td>
</tr>
</tbody>
</table>

Figure 4.1 illustrates the same results schematically.

![Map of the United States showing the design-build statutory status of states](https://pao.cnmoc.navy.mil/educate/zeus/images/usa_map.htm)

Figure 4.1. Design-Build Statutory Status of all the States in December 2006

[The blank U.S. Map was downloaded from an educational website belonging to U.S. Navy](https://pao.cnmoc.navy.mil/educate/zeus/images/usa_map.htm)
Construction Management-at-Risk (or CM/GC)

Based on the search done in the 50 state codes, 14 states have authorized their DOTs to use CMR in their projects. For example, in North Carolina (N.C. Gen. Stat. § 143-128.1) the construction manager at risk shall contract directly with the public entity for all construction; shall publicly advertise; and shall prequalify and accept bids from first-tier subcontractors for all construction work under this section.

Construction Management at Risk is allowed to be used in DOT projects in two states only after obtaining an extra approval. For example, in Massachusetts (ALM GL ch. 149A, § 1) it is mentioned that “prior to using the construction management at risk delivery method, the public agency shall obtain a notice to proceed from inspector general.”

It is possible to use Construction Management at Risk in three states but with limitations in each fiscal year. For example based on the Minnesota legislation, (Minn. Stat. § 16C.34), construction manager at risk contracts may be used but not for “more than five percent of its total projects let, by number, in each of the fiscal years 2006 and 2007, and ten percent of its total projects let, by number, in each fiscal year thereafter.”

Most of the states have not passed a law which allows DOTs or even other public entities to use CMR in their projects. This research shows that 31 states have not accepted CMR as a legal project delivery in public projects. All the 50 states are categorized in Table 4.2, as to the legality of the CMR.
Table 4.2. Legal Status of States regarding the Use of Construction Manager at Risk in Transportation Projects

<table>
<thead>
<tr>
<th>Fully authorized</th>
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<th>Authorized for a pilot program and/or with some limitations</th>
<th>Not authorized</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ, AR, CT, GA, KY, ME, NH, NC, SD, TN, UT, VA, WV, WY</td>
<td>MA, OR</td>
<td>MN, TX, WA</td>
<td>AL, AK, CA, CO, DE, FL, HI, ID, IL, IN, IA, KS, LA, MD, MI, MS, MO, MT, NE, NV, NJ, NM, NY, ND, OH, OK, PA, RI, SC, VT, WI</td>
</tr>
</tbody>
</table>

Figure 4.2 illustrates the same results for Construction Management at Risk.

Figure 4.2. Construction Management at Risk statutory Status of all the States in December 2006
Public Private Partnership

Although PPP is somewhat similar to DB in technical aspects, financial obligations have made legislators sensitive about it and the number of states which authorize DOTs using PPP in their projects is fewer than DB. The search done shows that as of December 2006, 24 states have accepted PPP as a delivery system. Among these states, four have put some limitations on PPP applications. For example, Department of Transportation in Oregon is required to have a research and development program for PPP.

State of Washington has authorized its DOT (WSDOT) to use PPP but is subject to an approval from a review panel chosen by the governor. Nineteen other states have fully authorized DOTs to use PPP. As an example, State of Illinois has this statute in its state code: “The Department is authorized to enter into agreements with any public or private entity for the purpose of promoting and developing high-speed rail and magnetic levitation transportation within this State.” Other states have more or less the same statutes and they are mainly about toll ways, bridges or railroads which can recover the capital expenditure by collecting tolls or fares from the users.

Table 4.3 shows the legal status of PPP in the 50 states.
Table 4.3. Legal Status of States regarding the Use of Public Private Partnership in Transportation Projects

<table>
<thead>
<tr>
<th>Fully authorized</th>
<th>Authorized but needs extra approvals</th>
<th>authorized for a pilot program and/or with some limitations</th>
<th>Not authorized</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL, AK, AZ, CO, DE, FL, GA, IL, IN, LA, MD, MN, NC, NJ, PA, SC, TX, UT, VA</td>
<td>WA</td>
<td>CA, MO, OR, RI</td>
<td>AR, CT, HI, ID, IA, KS, KY, ME, MA, MI, MS, MT, NE, NV, NH, NM, NY, ND, OH, OK, SD, TN, VT, WV, WI, WY</td>
</tr>
</tbody>
</table>

Figure 4.3 illustrates the same results for Public-Private-Partnership.

![Map illustrating the status of Public Private Partnership](image)

Figure 4.3. Public Private Partnership Statutory Status of all the States in December 2006
Regulatory and Statutory Limitations

Public agencies have found that the traditional way of awarding and executing a project is not necessarily the best way of delivering all the projects; not using other methods of project delivery in public construction is actually foregoing some opportunities of adding value to the money spent on these projects. This has been the main motive for states to pass various laws which allow other methods of procuring construction projects. Some potential issues include conflicts between the lowest cost-based bids of contractors vs quality-based selection of A/E in Design-Build, the fear of favoritism and unnecessary added cost in CM-at-risk, and lack of experience and loss of control over constructed facilities in a PPP project. These concerns have negatively affected the lawmakers and they have been hesitant to authorize public agencies in using these new methods. Because of this, there has often been a transition phase between the “only DBB authorized” and “all methods authorized”.

In the transition phase some limitations are put forth for using a method. For example, in some states only a few pilot projects are allowed to use the method and these projects should be first selected by a board specified in the state code. In Virginia for example, a “review board” defined in the state code has the duty of deciding on project delivery methods. In other words, this board studies each project suggested for utilizing Design-Build or Construction Management at Risk and approves or rejects the proposal. (Va. Code Ann. § 2.2-2405 (2006)).

While the process of passing the legislation to authorize alternative delivery systems have been slow at times, especially in some states, it seems that in general, the trend is toward
authorization (Ghavamifar and Touran 2008). It should be remembered that the first
design-build transit projects were authorized in 1994. At the current time, numerous
transit projects are constructed throughout the United States using the design build
approach. Two surveys on Design-Build done in 2002 and 2006 show that the number of
states which authorize this system has increased from 30 states to 37 states. (Nossaman et
al 2006). With the emphasis on constructability and the need to deliver projects in a
shorter time-frame, there is reason to believe that this trend is going to continue in the
future.

Advantages and Disadvantages of Project Delivery Methods

Transit agencies need to consider numerous factors when deciding to select a project
delivery method. Some of these factors are relevant to the evaluation of PPP method and
the rest should be used when comparing the performance of other delivery methods
(DBB, DB, and CMR). The second group of these influencing factors and their
interactions with different project delivery methods are studied in this part of the chapter
in the format of a descriptive pro-con analysis. In order to identify these factors a
thorough literature search, case studies and interviews with project directors were
conducted. These factors are categorized as follows:

1) project-level issues
2) agency-level issues
3) public policy/regulatory issues
4) life cycle issues, and

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4 The interviews were conducted for the TCPR Guidebook and the author participated in a number of those
interviews. The following part (which is based on all the interviews conducted in TCRP research project,
the literature search, and case studies) has been a major contribution of the author to the TCRP Guidebook.
5) other issues.

Table 4.4. Pertinent Issues in Project Delivery Method Selection among Design-Bid-Build, Design-Build, and Construction Manager at Risk

<table>
<thead>
<tr>
<th>Project Level Issues</th>
<th>Agency Level Issues</th>
<th>Public Policy/Regulatory Issues</th>
<th>Life Cycle Issues</th>
<th>Other Issues</th>
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<tbody>
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<td>• Project Size</td>
<td>• Agency Experience</td>
<td>• Competition</td>
<td>• Life-Cycle Costs</td>
<td>• Construction Claims</td>
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<td>• Cost</td>
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<tr>
<td>• Risk Allocation</td>
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<td>• LEED Certification</td>
<td>• Third Party Agreement</td>
<td>• Stakeholder/Community Input</td>
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</table>

Each pertinent issue is defined first and then the advantages and disadvantages of each delivery method with respect to that factor are listed. These critical points will then be used in decision making. The decision making procedure is explained in the following parts of this chapter.

**Project-Level Issues**

Project-level issues are specific to the project under consideration and include such items as project size, cost, and schedule, as well as project-specific risk management/allocation and possible certification for sustainable design and construction.

1) **Project size**: It reflects the dollar value and physical dimensions of the transit project. Transit projects are usually larger than $100 million in value; however, transit agencies sometimes get involved in smaller projects such as construction of parking garages. By
studying this issue one seeks to determine which delivery method is suitable for a project with a given size, and how changing the size may impact the choice of delivery method. Intuitively, project size would influence the choice of delivery method. However, current literature and the case studies conducted in this research, document successful projects in a range of sizes using DBB, CMR, or DB project delivery methods. Because each of the three main delivery methods can be applied to projects of all sizes, this issue needs to be considered in combination with other issues such as schedule, agency staffing, risk management, and others.

2) **Cost:** This issue represents several aspects of project cost like ability to handle budget restrictions, early and precise cost estimation, and consistent control of project costs. In other words this issue checks the abilities of each delivery method in terms of cost control and cost estimate.

**DBB:** This delivery method may benefit from competition in the market and get low bids when bidding out a project. Having a complete design before awarding the project increases the certainty about cost estimates because the owner has the engineer’s estimate as well as several estimates submitted by the bidders. The level of cost certainty increases even more when the payment method is lump-sum. As an advantage for DBB, transit agencies can choose unit price bids as the payment method when the project line items and their cost estimates are known but the quantities are not known with certainty. This payment method allows the constructor to bid on unit prices rather than the total price. In this way, the constructor does not have the risk of fluctuating quantities, while the owner will not have to pay for constructor’s contingencies included in the bid because of quantity uncertainties.
**CMR:** This delivery method has two main characteristics relevant to project cost: 1) it is usually combined with a GMP payment mechanism and 2) the constructor is involved in the project before bidding the project out. These two characteristics directly affect the performance of this delivery method in regards with project cost. As an advantage, there may be cost savings because of early constructor's inputs to the project (Oregon Public Contracting Coalition 2000) and also competitive pricing through "open book" accounts (Irwin 2003). Usually, the owner can negotiate and set the GMP at about 60% design complete (AGC 2004). It is advisable that in case the project requires the services of major trade or specialty subcontractors, to bring them on board during the design phase. This way, the project team can benefit from their knowledge and experience and establish a more reliable budget early on. The drawback is losing the opportunity of putting this work to bid. Potential schedule compression by some overlap between design and construction will be an advantage to CMR if the escalation rate has a significant effect on the project cost escalation. Also, compared to the traditional DBB method, the owner will know the estimated cost earlier in the project life-cycle. But at the same time the owner needs to have a close cost monitoring on the project because of the cost reimbursable payment method (Walewski *et al* 2001). Also, it is somewhat difficult to evaluate the validity of the GMP compared to a traditional bid process.

**DB:** DB has a relatively good performance when there is budget restriction (Gordon & REES LLP. 2005) because it reduces the potential of cost overruns due to claims and delays. A TCRP study shows that there are fewer cost overruns in DB (TCRP 2002). Another study shows that DB outperforms CMR in O&M costs, unit cost, and cost growth (Konchar *et al* 1998). DB can also provide the owner with an early cost estimate.
Through the use of a lump sum contract in a DB procurement, the owner can establish a firm cost estimate relatively early in the process (Walewski et al 2001; Gransberg et al 2007). The AASHTO Procurement Guide states that DB gives earlier cost certainty and has less cost growth compared to traditional DBB (Molenaar 2005b).

3) **Schedule:** This factor shows two aspects of project schedule and includes both the ability to shorten the schedule and the opportunity to control and prevent time growth. In other words this issue checks the abilities of each delivery method in terms of schedule control and schedule compression.

**DBB:** Design-bid-build has a sequential process and usually does not have room for schedule compression. This sequential process results in a longer schedule compared to the alternative delivery methods (Walewski et al 2001; Gordon 1994). A lengthy schedule is the price that is paid for the owner to have the project designs completed prior to the project award. DBB is weak on schedule growth control compared to other delivery methods. The NCHRP Best-Value contracting study found that DBB projects had the greatest average time growth (Scott et al 2006). Lack of ability to compress the schedule and control time growth due to delays caused by design errors in DBB has been one of the main reasons for owners to choose other delivery methods. One way of compressing DBB projects is to break down the program into several packages and let each package separately (TCRP 2009). One problem in this approach seems to be the coordination effort required and the issue with abutting primes.

**CMR:** Having a constructor on board helps the project team develop a more practical and doable schedule for the project. A study has shown that CMR has the ability to meet or
exceed schedule requirements (Minchin 2007). This delivery method can also help the owners with projects that are schedule sensitive (Walewski et al 2001) and can save some time in the project because of concurrent design and construction (Oregon Public Contracting Coalition 2000).

**DB:** Flexibility in schedule increases in this delivery method because designer and builder are one entity (Oregon Public Contracting Coalition, 2002). Many experts believe that DB results in a faster schedule delivery (Walewski et al 2001; Konchar et al 1998; Gransberg et al 2007; Molenaar et al 2003) and has the least schedule growth (Konchar et al 1998, Scott et al 2006). Another effect of DB is earlier schedule certainty (Molenaar et al 2005) because the design-builder submits the project schedule at the time of contracting which is comparatively early in the project life. Another important characteristic of DB for transit agencies is that it obligates design and construction funds before the end of a given fiscal year (Gransberg et al 2007). This can help the agencies award the project and allocate the available fund to a project without waiting for its design to be absolutely complete.

**4) Risk management:** Each new project has some level of uncertainty during various phases of its project development. Methods to cope with these uncertainties are inherent to each delivery method. The effect of delivery methods on risk identification, quantification, and mitigation is different; therefore, selection of a delivery method is dependent upon the owner’s risk management approach. These differences are considered under this issue. Tier 3 of the selection system developed in this dissertation is based on risk allocation. Also, it should be noted that the effect of risks is prevalent in many of the issues discussed in this chapter and is not limited to the items 4 and 5 of this chapter.
**DBB:** This delivery method has a long history of application and a rich background in terms of statutory laws and standard contracts which entail developed risk management processes. When the project scope is clearly definable, the owner of a transit agency can follow the traditional methods of managing risks in DBB (Gordon 1994). Although risks and rewards are easy to understand in this method, disputes arise often over authority, responsibility and quality (Walewski *et al.* 2001). In other words having separate contracts for design and construction may or may not help the owner manage the risks of a transit project and the owner’s success in mitigation of risks depends upon the proficiency and experience of the owner and its consultants in risk management.

**CMR:** The risk for the construction manager at risk comes from the CM holding the trade contracts and taking the performance risk of the project (AGC 2004). The use of a guaranteed maximum pricing structure can create a mechanism to share cost risk between the constructor and the owner agency in the hopes of ultimately reducing costs. Early constructor involvement may result in a better understanding of the project risks and more efficient risk allocation can be achieved. This delivery method is conducive to team work. The constructor shares information with the owner and designer on trade subcontracts, value engineering, etc. That is why some experts believe that CMR theoretically reduces the risks of every entity involved in the project (Minchin 2007).

**DB:** Risk allocation and risk management are inherently different in DB delivery compared to DBB and CMR. The risk for errors and omissions in the plans is transferred from the owner to the DB contractor. Having single point accountability for design and construction helps the owner avoid designer-constructor blaming each other on changes in cost or time of project execution (TCRP 2002; Riley *et al.* 2005; Irwin 2003). From the
owner’s perspective, the DB approach reduces the size and frequency of change orders (Molenaar et al. 2003; Riley et al. 2005). Agencies should realize that though the risks are contractually transferred to the design-builder, a poorly defined initial scope in the RFP may result in significant cost increases. According to the design-builder’s scope of work which includes the project design, the DB constructor may be required to have errors and omissions insurance (which is usually required from design firms) in this transfer of risks (AGC 2004; Irwin 2003). In essence, the risk for errors and omissions does not go away, but it is transferred to the DB contractor, who can hopefully manage the risk better than the owner in the DBB system.

5) Risk allocation: Research in the area of risk management has indicated that the most effective approach in risk allocation is to assign project risks to the parties in the best position to manage them. This means that the party assuming a certain risk should be the party who has the most control over that risk and is also most likely to survive the negative impact of such risk. The main vehicle for risk allocation is the contract. The type of project delivery method will have a profound impact on risk allocation. Some methods allow the owner greater flexibility in allocating risk to parties involved. Tier 3 of the project delivery method selection system developed under this dissertation is based on an effective method of risk allocation. As an example, schedule risk is sometimes addressed by choosing a DB approach. This was covered earlier under Item 3. It is emphasized that risk allocation affect many of the pertinent issues discussed in this chapter and is not limited to Items 4 and 5.

DBB: This delivery method can help the owner divide risks between the designer and the contractor, but the risk of additional construction costs resulting from erroneous design
remains with the owner (AGC 2004). Scope definitions of design and construction contracts in DBB play an important role in risk allocation. The owner will face challenges if the duties are not defined clearly and ambiguity remains in the contracts.

**CMR:** Although CMR facilitates risk management, it is not necessarily the best method for risk allocation. Having an experienced constructor on board improves the whole process of risk management including risk allocation but the increase in the number of parties directly involved in the project and some overlaps between their duties may make the risk allocation more difficult (TCRP 2009). Although GMP as a means of risk allocation should decrease the owner’s risks there is always a possibility that the owner and the on-board contractor do not come to an agreement on GMP in a timely fashion. The owner in this case may have to bid out the project and will suffer from the resulting delay imposed on the project and will be subject to the uncertainty of getting higher than expected bids.

**DB:** Because design-builder is the single point of responsibility in this delivery method, risk allocation is simpler. The owner must carefully decide which risks it can best manage and assign the design-builder those where it is the best party to bear the risks. It is not wise to allocate total risks to the DB contractor because that would drastically increase the contingency and constructor’s insurance costs which will be transferred to the owner through the bid (AGC 2004). Examples of other risks include the risk of obtaining various environmental permits, or purchasing the real estate. Experience shows that the owner is in the best position to assume these risks (TCRP 2009).
6) **LEED certification:** Sustainable design and construction features are becoming more common and may become mandatory in the future for public infrastructure projects. Thus, it is important to gauge a project delivery method’s ability to include these features in accordance with the owner’s needs. The US Green Building Association’s Leadership in Energy and Environmental Design (LEED) certification is often used by public agencies as a means to articulate its desire to design and build both energy efficient and environmentally responsible projects. Although LEED certification has not become a requirement in transit projects, how each delivery method facilitates this issue can be a benefit or a drawback. For example, one benefit of establishing LEED as a criterion is that it can be used as a metric to evaluate sustainable design and construction options regardless if LEED certification is sought for the project. LEED prerequisites (including selection of site, and construction activity pollution prevention) can yield greater environmental benefits while reducing regulatory risk. On the other hand, LEED requirements may increase project costs because of extra tasks and documentation. One important fact to remember is that the LEED standards are in the process of diversifying to accommodate a range of project types. The adoption of LEED criteria as a selection requirement may need to be phrased to include the most current iteration rather than a particular standard. Moreover, the LEED standard has been considered to be less progressive than alternate methods that take into account carbon neutrality.

**DBB:** The owner has a clear opportunity to define sustainable design with LEED criteria. The lack of builder input can limit opportunity for input into sustainable design opportunities and the owner, in certain cases, can thereby risk losing LEED certification.
**CMR:** The owner has a clear opportunity to define sustainable design with LEED criteria. Sustainable construction features are more likely to be implemented considering the cooperative nature of the owner/builder contracts.

**DB:** The owner can clearly articulate its expectations regarding the use of LEED criteria by assigning weight in relation to other factors in the DB evaluation plan as well as using sustainable design and construction as performance criteria during design and construction. There is some evidence that the use of DB may hamper the objective of achieving LEED certification. This is due to the perception of risk by the DB contractor when considering whether to bid on a DB project with LEED goals. The owner needs to be cautious in defining the project scope and goals clearly to ensure reasonable competition, especially if LEED certification is desired.

**Summary**

The results of interviews and the literature review show the important role of project-related issues in selecting a delivery method. Some factors like project schedule and cost were chosen by almost all the interviewees as factors that directly influence their decision. It was clear in the interviews that project size does not have an independent role in delivery method selection. This section explained the advantages and disadvantages of each delivery method in regards with those issues. It also expanded the discussion to other factors like risk management and LEED certification that are clear distinguishing factors while studying the abilities of each delivery method.
Agency-Level Issues

Agency-level issues relate to the owner agency. These will include items such as experience with various delivery methods, workforce requirements, goals and objectives for the capital improvement program, control of the project, and third party agreements.

7) **Agency experience:** This issue focuses mainly on the level of experience of an owner’s staff in terms of alternative delivery methods application. It shows the interaction between the level of experience and comfort and confidence using a specific delivery method. Owners who have used a project delivery method in the past would have a higher level of experience with that method.

**DBB:** Transit agencies have historically employed DBB project delivery. This historic experience with DBB makes the delivery method a good candidate (TCRP 2002). This experience can be a motivator or a detractor for using alternative delivery methods. The most experienced owners may find that some of their negative experiences with DBB (e.g. contractor’s claims, erroneous designs, delay in schedule, and cost overruns) will push them to try alternative methods. Other owners will be comfortable with DBB delivery and therefore be hesitant in trying new delivery methods.

**CMR:** Most of the agencies have not applied CMR in their projects, as this is a relatively new method in transit. The agencies’ experience with CM is mainly about hiring a construction manager as a consultant (or Agency CM) (Please refer to Chapter 2 for detailed discussion on the CM definition). Nonetheless, agency staff with DBB management experience should have most skills necessary to manage CMR because of the similarities between CMR and DBB (TCRP 2009). One missing skill may be
negotiating the construction manager’s preconstruction services fees and the guaranteed maximum price (GMP) in CMR.

**DB:** There have been several examples of transit projects executed with the DB approach. Many transit agencies as well as other public agencies have managerial experience required for a DB project. Although agency staff with DBB management experience should have most skills necessary to manage DB, the differences between DB and DBB are significant enough that some sort of training seems to be inevitable for agencies with no background in DB. The primary difference is managing a contract that contains the designer and constructor as one entity. This difference affects the manner in which the design-builder is procured (*e.g.* using best value method instead of bidding based solely on cost), the manner in which design is reviewed, and some aspects of how construction is overseen by the owner. Additionally, agency staff will need to learn how to conduct project oversight without the presence of a completed design for early features of work. This may require training and change of skills of owner employees which may make DB more difficult to administer.

**8) Staffing Required:** This issue reflects how each delivery method drives the owner’s direct involvement in the project. Each delivery method assigns specific duties to each party including the owner. The scope of these duties and the dependency of the project progress on the owner’s involvement in decisions show the extent of owner’s involvement. The total number of required owner’s employees for each delivery method is one measure of the extent of owner involvement. A second measure is the variation in the number of staff required throughout the project development process. It is assumed that in general, a smaller staff is more desirable, although this has to be measured against
potential reluctance within the agency to buy into a method that can reduce the need for agency staff.

**DBB:** An owner in a DBB project should administer two separate contracts for design and construction. Because of this and the high level of involvement in decision making and quality management, a relatively large number of owner employees are needed in this system (AGC 2004; Gordon 1994; TCRP 2009). The owner’s responsibilities in DBB are spread throughout the project (mainly dealing with the designer at the beginning and shifting to the contractor after project award); fluctuation in the number of employees required during the project is minimal.

**CMR:** The owner hires a new party in CMR and delegates some parts of its managing duties to this party. This system can arguably require the least number of owner’s employees because the CMR can expand to meet the owner’s staffing needs (Gordon 1994). The owner may however need to add some professionals to its staff (either as an employee or consultant) if special expertise (GMP or construction manager’s fee negotiation as an example) in managing a CMR contract is desired.

**DB:** The owner of a DB project should carefully develop project specifications before advertising the project because the design-builder takes responsibility for the project in both design and construction phases only after the project awarding and will base the project design on the specifications. The owners may hire consultants for developing the bid documents or use their own staff. A study shows that most of the agencies have not changed the size of their staff after implementing DB mainly because the owner must be involved with substantial amount of pre-advertising design and engineering effort.
(Gransberg et al 2007). Another study shows that some public agencies had spent considerable effort in developing of design documents as a means of performance risk reduction in large DB projects (Molenaar 2005a). The number of staff required for project administration decreases after the award as the number of check points and controls is reduced in this delivery method and the oversight procedures are usually streamlined (TCRP 2002). Another driver with respect to the size of staff is the way QA/QC is handled in DB projects. In most DB projects, the constructor is put in charge of day-to-day quality control functions. The owner’s role is limited to spot checks and quality assurance functions.

9) Staff Capability: This issue mainly focuses on the quality and competence of the owner’s employees. This factor seeks to measure the owner’s requirement to furnish a highly capable staff to complete the duties it must undertake in each delivery method. The availability of the experienced staff until the end of the project should be considered while evaluating the staff capability.

DBB: Transit agencies have more experience with DBB. This experience helps them gradually build up the capability in their staff at all levels of the organizational chart. An important issue here is the different expertise required in owner’s agency to handle a design contract with the designer of project and a construction contract with the general contractor. So the owner may end up with a longer list of required competencies (TCRP 2009).

CMR: Some professionals believe that CMR requires special capabilities to administer this type of delivery method while others think that the owner agency is delegating most
of its duties to the CMR. While the work can be delegated, agency staff must have the capability to oversee CMR work and notice errors or omissions in their work (TCRP 2009). Another managerial skill required in CMR is related to the relations between the onboard constructor and the designer. The owner should carefully manage the process by which the constructor gives inputs (constructability, value engineering, etc) to the designer, and the way these inputs are received, analyzed and implemented. Designers are not used to taking on-going criticism by a contractor and there is potential for this process to cause conflicts. Also, the experience of the agency staff in GMP negotiations seems to be the key in this delivery method; While the agency would need a smaller staff in this method, the staff needs to be especially competent and versatile in dealing with these additional requirements.

**DB:** As an alternative delivery method, DB contracts require owner’s competency in terms of managing the process, keeping up with the speed and understanding the procedures. A recent research shows that the traditional design and construction engineering tasks performed by public agency professional engineers (e.g. design deliverable approvals, construction inspection) were performed by the same staff in the design-build projects (Gransberg et al 2007). While the required skills for DBB are similar to DB, owners tend to put their most experienced staff on DB projects because they need to be better prepared to understand conceptual designs, conceptual estimates, and performance criteria. These skills are typically only found in the most experienced staff (Gransberg et al 2007; TCRP 2009).

**10) Agency Goals and Objectives:** Agency goals can be described in broad terms such as providing service to the community or achieving its growth goals. Agency goals can
align with project delivery attributes or can be in conflict with them. Agency goals are different from project goals. Agency goals also entail statutory requirements for safety, equal opportunity, and other legal/regulatory requirements. Project goals on the other hand are specified in procurement documents and are usually described in terms of time and cost expectations.

**DBB:** An agency can incorporate its goals and objectives in prescriptive specifications and detailed designs. Having control over the design on one hand and requirement of design approval for construction commencement on the other hand helps the owner assure the achievement of its goals and objectives. Examples include specifying targets for DBE participation and stakeholders concerns with regard to agency and project objectives.

**CMR:** The agency can work with CMR during the design phase, and when negotiating the GMP to develop project goals and objectives in alignment with agency goals and ensure that they are achieved by the project. Since this is typically a qualifications-based selection, the request for proposal can help assure that agency goals and objectives are clearly incorporated in CMR proposals. Furthermore, this delivery method may contribute to a better relationship between owner and constructor compared to DBB that can facilitate the achievement of agency goals (TCRP 2009).

**DB:** Compared to DBB, the DB approach reduces the agency’s control over the details of the design. To the extent that these details affect the agency’s goals, the DB may have a negative impact on achieving its goals. Examples of the agency goals that could be compromised include aesthetic considerations, safety, and commuter satisfaction. If an
owner is not absolutely clear on its goals prior to procurement, DB can yield unsatisfying results (Molenaar 2005b; TCRP 2009).

11) **Agency Control of Project:** Different delivery methods have different check points and decision making steps. Owner’s control over the details of design and quality of construction is studied in this issue while cost control and time control are studied in other issues.

**DBB:** The owner in this delivery method may benefit from checks and balances by having the designer and constructor under two separate contracts. Having periodic decision points in DBB and mainly during the design phase helps the owner control the project’s design (TCRP 2002; Garvin 2003; Irwin 2003). Having a specific contract based on bid plans helps the owner control construction and material quality. The owner will have objective control over the quality of design through the design team. Also, if flexibility is required during the construction, DBB can comparatively have a better performance because there are established procedures for implementing changes (although any change order may incur cost increase).

**CMR:** The owner agency benefits from the involvement of the construction manager in most of the decisions during the design phase. The construction manager can assist in controlling the details of design. The owner therefore has a similar level of control in CMR as compared with DBB if the working relationship with the CMR is good. This delivery method gives more control and flexibility to the owner in implementing changes in the details of design during design development compared to DB. Furthermore, having
the construction manager on the team may make implementing changes more effective than in DBB. (Walewski et al. 2001; Minchin et al. 2007).

**DB:** Although DB arguably provides the owner with the same quality of design and construction as DBB does (Konchar et al. 1998; FHWA 2006), most professionals agree that the owner will lose control over the details of the design that are not defined in the request for proposal. Loss of control over the design and lack of checks and balances have the potential to expose the owner to shortcomings in the quality of design and construction (Gordon & REES LLP 2005; Irwin 2003; Gransberg et al. 2004).

**12) Third Party Agreement:** This issue concerns each delivery method’s impact on facilitating agreements with third parties, such as political entities, utilities, railroads, etc. involved in the progress of project.

**DBB:** DBB can help during lengthy negotiations with some project stakeholders (TCRP 2009). It gives some flexibility and time to the owner to get required agreements before the commencement of construction phase. Third parties on the other hand, will have the ability to examine 100 percent complete designs before a contractor is hired. The disadvantages of completing designs before hiring a contractor may include a lengthy design schedule (including numerous instances of stakeholder inputs that can disrupt the most generous schedules) and also a lack of construction contractor input into the third party agreements.

**CMR:** The main advantage of having a construction manager is the constructability advice (construction knowledge and an understanding of construction methods) during the development of third party agreements. This delivery method may also have a
significant impact on getting into an agreement with third parties involved in a project when compared to DBB if the owner includes the responsibility to make agreements with third parties as part of the CMR contract. As an example, among the projects interviewed for this work, one agency clearly mentioned the benefit of having a contractor on board while negotiating with third parties (TCRP 2009). In general, the CMR’s knowledge of construction processes and sequencing can help clarify various aspects of project impact on communities and institutions; this should facilitate achieving understanding and approvals.

**DB:** The DB process can move third party agreements earlier in the delivery process, often before the design is complete. Agencies have experienced both benefits and drawbacks of having the design-build contractor on the team before all third party agreements are in place. As the design and construction is awarded in one contract, the time required to develop agreements with other parties can be shorter than desired. Additionally, these agreements must often be written in performance terms because the design is not completed at the time of award. However, some other experiences with DB show that the DB contractors have been successful in obtaining responses from project stakeholders by exerting pressure on them. The constructors have different approaches to negotiating agreements with third parties compared to owners and these can often be very effective (TCRP 2009).

**Summary**

Agency level issues directly impact the agency’s operations and its project delivery staff. Some of these issues such as experience and capability of agency staff play an important
role in switching from traditional DBB to its alternatives, CMR and DB. These issues usually have correlations with each other. For example, seeking more control over the project may result in fewer opportunities for transferring project risks to the designer and constructor\(^5\). However, when considering these issues as a decision making factor, it is mainly about the owner’s control over the project and flexibility in design phase. In all cases, the agency’s ability to articulate well-defined project objectives and a clear scope using the given delivery method is a key to success.

*Public Policy/Regulatory Issues*

Public policy/regulatory issues analyze the choice of project delivery method decision in the face of existing laws, mandated social programs, labor unions, and other factors that establish the legal environment in which the project must be delivered.

13) **Competition:** Each delivery method may affect the level of competition. In many cases, agencies are operating under a legal requirement which requires “free and open” competition. The owners benefit from a competitive market mainly because of the reduction in bid prices; so if the choice of a certain delivery method reduces the level of competition among bidders (or reduce the number of qualified bidders), it would be considered a disadvantage. Currently, the volatility of bid prices in transportation projects is a major concern for the owners of transit (and other modes of transportation) projects. Additionally, alternative project delivery methods may inadvertently lead the agency to package projects in sizes that can effectively reduce competition due to bonding.

\(^5\) An extensive discussion on the relation between project risks and owner’s control is published in a paper in the *Journal of Management in Engineering.*
limitations and contractors’ capacities. This factor is about the evaluation of facilitating effects of each delivery method on competition.

**DBB:** Compared to other delivery methods, availability of a relatively large pool of potentially qualified bidders ensures a high level of competition (Walewski *et al* 2001; AGC 2004). The owner can benefit from this market competition and get a low bid/proposal for its project. This approach also enables the owner to divide the project into smaller packages and bid them separately to further increase competition. The drawback to the multi-prime approach is that the coordination between various contracts may prove difficult.

**CMR:** Using RFP procedures and taking into consideration qualifications-based factors when evaluating the bidders can help the owners weed out unqualified proposers. The issue in this system is that the selected CMR becomes the winner of the construction contract, giving the owner less competitive leverage when pricing the construction (Irwin 2003). This can be alleviated to some degree by requiring that the project components be bid competitively among various trade subcontractors. Also, the owner can reserve the right to go to regular bidding if it cannot agree on the GMP with the CMR.

**DB:** The RFP process can weed out unqualified DB entities but at the same time, the size of the bid package and the bid preparation costs may reduce the number of qualified bidders (AGC 2004).

14) **Disadvantaged Business Enterprise (DBE) Impacts:** Delivery methods may facilitate the fair competition for DBEs for DOT-assisted contracts and reduce burdens on small businesses. The effect of each delivery method on promoting participation by
disadvantaged businesses is evaluated under this issue. In general due to the size of most transit programs, it would be unlikely that a DBE firm serve as the lead constructor. What is more common is to set aside a certain percent of budget to assure DBE participation.

**DBB:** The owner has the chance to include requirements for participation in both design and construction contracts. For example, in the RFP for soliciting design services, the owner may stipulate the nature and extent of DBE participation as part of the design team. In the same way, the owner may require that the general contractor perform a pre-set percentage of construction using DBE subcontractors. Usually, the minimum level (as well as the desired target level) of participation is stipulated in terms of percent of contract price. On the other hand, the low bid environment may force DBE subs to submit dangerously low prices, potentially harming the future viability of these fledgling companies.

**CMR:** A constructor that submits a proposal for a CMR project is usually more sophisticated than a DBB construction contractor. Lack of enough experience is a negative point for DBEs in a qualifications-based selection. One method to ensure DBE participation is to require a pre-set minimum (and target) percentage of the GMP for DBE firms when the GMP contract is negotiated.

**DB:** Lack of enough experience and finance does not allow a DBE to become the main contractor but small businesses/DBEs may become subcontractors of the design-builder. As the owner is not directly involved in selecting subcontractors and suppliers, requirements for DBE participation as a percentage of the project budget should be included in DB RFP and then in the contract. This should be based on the number of
DBEs associated with the various trades that will be required in the project (Florida DOT DBM RFP 2007). The design builder should report (usually monthly) actual payments to all the DBE subcontractors and suppliers. As the owner has less control in this delivery approach, the enforcement of DBE participation may be harder than DBB or CMR.

15) Labor Unions: Each delivery method covers certain phases of a project life cycle. For example, Design Build Operate and Maintain (DBOM) delivery covers almost all the phases while DBB delivery only affects the construction phase. The choice of delivery method may have an impact on labor usage and hence labor union issues. The legal protections for transit laborers such as Section 13 (c) of Federal Transit Act complicates the application for federal grants and transit agencies should show that fair and equitable protective arrangements are made to protect employees affected by such assistance.

DBB: This is the traditional way of doing the project in which the contractor hires the laborers directly or through a subcontractor. Union or non-union laborers may be used in this approach (unless local conditions and considerations limit constructor’s options) and there would be no fundamental opposition to DBB unless the contractor does not comply with the relevant rules and regulations set forth.

CMR: The constructor in this delivery method plays a similar role to the contractor in DBB and there would not be fundamental issues between the unions and the constructor. If there are union issues in the project’s location, the constructor does not usually guarantee the maximum price of the project and may not absorb the risks of the labor union issues. Unions may support alternative delivery methods as these methods give
more weight to qualifications rather than cost; unions claim that they are more qualified than non-union labor (Bearup et al 2007).

**DB:** Design-builders are usually joint ventures and dissolve after the end of the project. This may make the process of dealing with unions a bit complicated as they expect a reliable and established party to have an agreement with. Awarding the design to a design-builder in some cases (California for example) where public design engineers have their own unions may cause conflicts and challenges for the owners who seek to use DB. Unions may support alternative delivery methods as these methods give more weight to qualifications rather than cost; unions assert they are more qualified than non-union labor (Bearup et al 2007).

**16) Fed/State/Local Laws:** Based on the research done on the federal and state laws, use of some delivery methods may not be allowed for transit agencies. Some of the states mandate that transit agencies go through several steps before being allowed to use an alternative delivery method. This issue studies the level of difficulty of using a delivery method from a legal standpoint. Due to constant changes in state and local laws, each agency should check all the relevant codes in order to find out the legality of each delivery method at the time when possible delivery methods are studied for each project. (Please refer to the previous part of this Chapter for more information on this issue).

**DBB:** All the state codes accept DBB as a project delivery method for a transit project. Relevant procurement processes are well-developed and details of DBB execution are available nationwide.
**CMR:** More than half of the states do not allow CMR to be used in transit projects (Ghavamifar and Touran 2008). Some have imposed limits or extra approval requirements and only about 14 states have fully authorized CMR application in transportation projects. Even in those cases, approval for transportation projects may not mean that CMR can be used in a transit project. Because of these complications, the legality of the CMR or any other alternative delivery method should be carefully reviewed in a specific state.

**DB:** This delivery method has been used more than CMR, but there are still 13 states where this delivery method is not allowed in transportation projects (Ghavamifar and Touran 2008).

**17) FTA/EPA Regulations:** The effect of various environmental regulations on project cost and schedule can be profound. These include obtaining various types of permits and complying with various regulations. Additionally, FTA specifies that a number of requirements be met before a project can receive commitment for federal funding (*i.e.* receive the Full Funding Grant Agreement (FFGA) in case of New Starts projects). Currently the FTA accepts all types of project delivery methods; specifically, they modified their evaluation process to accommodate DB and DBOM in the 1990’s.

**DBB:** The traditional approach is the most familiar for the FTA and the environmental agencies. This familiarity can be an advantage in the permitting and funding process.

**CMR:** FTA has less experience with CMR. This may cause some problems or delays although the agency maintains that it can accommodate all legal delivery methods.
Environmental issues would be similar to DBB as the owner remains involved and is in control throughout the design phase.

**DB:** FTA started an initiative to experiment with DB early in the 1990’s. Five pilot projects were constructed using the DB approach. FTA has since modified its procedures to accommodate the DB delivery method. The owner agencies prefer to receive the FFGA before the project goes to bid, while the project is at the end of Preliminary Engineering (PE) and subject to many uncertainties. The FTA had some problems with the first generation of DB projects. Currently, most of these problems have been resolved and the agency has matured in dealing with DB projects. The environmental permitting process can be problematic though. As an example, in a commuter rail project (TCRP 2009), a major cause of delay was that the owner had left the obtaining of environmental permits to the constructor, a task for which the DB contractor was ill-equipped. This caused a delay of longer than one year.

18) **Stakeholder/Community Input:** This issue discusses the opportunities afforded by the delivery method to the owner for coping with communities inputs. The delivery method should strive to leverage stakeholder and community input to achieve project goals in a meaningful and transparent fashion.

**DBB:** Separate design and construction phases give more time and opportunity to the owner to get stakeholders and communities’ inputs to the project design and incorporate their expectations in the project scope before the commencement of the construction phase. This characteristic of DBB can lengthen the project pre-construction phase and cause delays in the project.
**CMR:** The construction manager is on board during design in this method and can help the owner negotiate with stakeholders and understand their expectations while pushing the project forward. Additionally, community outreach and public information can be made as a part of the CMR’s preconstruction service package. Depending on the CMR’s experience and qualifications, this may enhance project chances for obtaining community consent and stakeholder agreements.

**DB:** The owner of a transit project needs to get all the important inputs from stakeholders before issuing a RFP because changes in the project after that would be difficult and costly. On the other hand, after the contract award, the DB contractors have sometimes been able to proceed through community pressure more effectively compared to state agencies (TCRP 2009). Additionally, the agency can require the DB contractor to include a public information and outreach program in the project to facilitate stakeholder input during design and construction.

**Summary**

Public policy/regulatory issues are factors that a transit agency has little if any ability to change, and include specific legal or governing body policy constraints on PDM use as well as requirements to satisfy legislative requirements for public works projects. Many of these issues are essentially a go/no-go factor that may eliminate a delivery method from any further consideration in the process of decision making (e.g. Fed/State/Local Laws). While some factors of this section are found to have minimal impacts on decision (e.g. DBE impacts) there are some other factors that strongly affect delivery selection such as competition.
Life-Cycle Issues

The life-cycle issues category attempts to place the project delivery methods in a long-term, post-construction context in the minds of the respondents. These issues deal with project aspects that impact not only maintainability and the cost of operations and maintenance, but also the sustainable design and construction goals that are starting to emerge as measures of an agency’s commitment to the environment.

19) Life-Cycle Costs: Effects of delivery methods are extended to the operation and maintenance phase. This issue focuses on the opportunities or barriers that each delivery method provides in regards to life-cycle costs.

**DBB:** The owner is in control of design and quality and can tailor these to project’s long-term life-cycle goals.

**CMR:** The owner keeps almost the same level of control over the design of the project and also benefits from constructor’s advice regarding future costs of project.

**DB:** The owner needs to have a close eye on the issue of increasing life cycle costs of the project mainly because the design-builder has a motive to decrease the initial costs of the project and bring it down to the agreed upon amount regardless of possible increases in the future operation and maintenance costs of the facility.

20) Maintainability: Maintainability is affected by the choice of delivery method in two different aspects: level of quality and ease of maintenance. This issue describes positive or negative effects of each delivery method on these two aspects.
**DBB:** The owner can check the maintainability of the finished design before awarding the project. Having check points in the design phase can help the owner assure the quality of the design of the end product.

**CMR:** The owner of a CMR project can benefit from all the advantages of DBB and also the constructor’s advice on maintenance of the end product if the constructor has previously operated similar facilities.

**DB:** As the quality control is transferred to the design-builder and details of the design are not known at the time of awarding, many owners have some concern about maintainability and quality of the end product. This has led some owners to require multi-year warranties from DB contractors.

**21) Sustainable Design Goals:** Sustainable design is becoming ever more important in helping to achieve sustainability goals for the projects. The effect of delivery method in facilitating the process of implementing sustainability issues in the design is the focus of this discussion.

**DBB:** The Owner has a clear opportunity to define sustainable design intent and shape social and environmental impact. This method presents opportunities to promote and enhance sustainable design criteria by allowing for materials research and the development of strategic stakeholder input. One drawback may be that the O&M personnel could ultimately be unfamiliar with sustainable systems operational requirements, but this is an issue that can be resolved with careful planning.

**CMR:** The owner has a unique opportunity to realize the economic returns for sustainable systems performance as well as using sustainability as an evaluation factor for
the selection of a builder. The design schedule could, however, outlive systems performance criteria and impact public participation limiting social equity issues.

**DB:** This project delivery method can result in an inherent coordination of design and performance with potential for accelerated economic returns for sustainable systems performance. The owner has an opportunity to use sustainability to evaluate potential design-builders although innovation with sustainable criteria could be limited. On the other hand, the owner can clearly articulate its expectations regarding sustainability by assigning weight in relation to other factors in the DB evaluation plan. The design schedule could, however, impact public participation thereby limiting social equity issues. Due to the normally time consuming processes associated with municipal and state requirements for mandatory announcement and the convening of public hearings, certain sustainability measures such as wetlands mitigation and avoidance of undeveloped areas raises concerns for eminent domain and brown fields redevelopment which can impact performance time.

**22) Sustainable Construction Goals:** Sustainable construction is an important vehicle for achieving sustainability goals for new projects. The disconnect present between designer and builder with some delivery methods can create limitations on the means and methods available to the project. The effect of delivery method in facilitating the process of sustainable construction is the focus of this discussion.

**DBB:** An experienced constructor does not have opportunity to give sustainable design features as inputs during the design phase. The availability of sustainable materials and
practices relevant to regional procurement and construction methodology may be unavailable to designers unfamiliar with the project location.

**CMR:** The owner has a unique opportunity to realize the economic returns for sustainable systems performance as well as using sustainability as an evaluation factor for the selection of a builder. Sustainable construction features are more likely to be implemented considering the cooperative nature of the owner/constructor contracts.

**DB:** This project delivery method can result in an inherent coordination of design and performance with potential for accelerated economic returns for sustainable systems performance. The owner has an opportunity to use sustainability to evaluate potential design-builders although innovation with sustainable criteria related to more advanced technology could be limited due to the lack of previous installations.

**Summary**

The importance of life cycle costs and maintainability of the facilities built in a transit project can not be overemphasized. Life cycle issues incorporate the project operation phase as well as design and construction phase. Sustainability issues in design and construction are studied here. Inclusion of this category of issues to certain extent guarantees the project compliance with environmental standards that are evolving.

**Other Issues**

The Other Issues category consists of issues that are important to project goals but not categorized previously in this part.
23) Construction Claims: The effect of each delivery method in exposing the agency to potential conflicts and claims is studied under this issue. If a delivery method can reduce the exposure to construction claims, that delivery method is a favorable choice and if it increases the possibility of construction claims, it is an unfavorable choice.

DBB: This method typically has the highest occurrence of claims and disputes. Disputes arise often over authority, responsibility and quality (Walewski et al 2001). Furthermore, as the owner is responsible for design completeness, errors and omissions claims is a common occurrence in DBB projects. Some contractors may bid low to win a job and try to enhance their final profit margin through claims and change orders, especially if design errors or ambiguities are present in the construction documents. Studies have shown that this delivery method resulted in the highest rate of cost growth which could be an indication of large number of claims (Konchar 1998).

CMR: Assuming a well-structured contract, there is less probability for claims and disputes once a GMP is agreed upon and the contract is signed. As the CMR has been present during the design process there will be less need for information and clarification of the design documents. Some professionals consider that this approach will result in very few construction claims. This is then a major advantage of the CMR approach (TCRP 2009). The qualifications-based selection methodology creates an effective deterrent to initiating claims by requiring the CMR to be “successful” on the current contract in order to be competitive for future projects. The qualifications-based selection process may reduce the possibility of hiring litigious contractors.
**DB:** A study shows that the size and frequency of change orders are less in DB (Riley et al 2005). This delivery method is less prone to claims and disputes, assuming a well-structured contract. As an example, claims for design errors, a major source of DBB contractors’ complaints, is reduced considerably in DB. At the same time, early pricing leaves the owner vulnerable to claims for scope that was missing in RFP. The qualifications-based selection methodology creates an effective deterrent to initiating claims by requiring the design-builder to be “successful” on the current contract in order to be competitive for future projects.

**24) Adversarial Relationship:** Transit projects can be hampered by conflicts between parties to the design and construction contracts. The higher the level of adversarial relationships in a project, the more likely the project will suffer from cost, schedule, and quality problems. Delivery methods define the relationships among all project parties. If the project delivery method encourages project parties to work together as a team to achieve the project goals and characteristics, it is considered a benefit. Conversely, if the project delivery method increases the possibility of adversarial relationships, it is considered a detriment.

**DBB:** This delivery method can create an adversarial relationship between the parties and mainly between the owner and construction contractor (Walewski et al 2001; Irwin 2003; Mahdi et al 2005). Furthermore, the engineer and the contractor may assume adversarial roles as one is in charge of approving the other’s work. The division of responsibilities may also result in these two parties blaming each other in case of project failures or during major disputes (Halpin 2006).
**CMR:** Including construction contractor collaboration during design phase builds constructive team work and facilitates project team formation (Irwin 2003; Minchin *et al* 2007) although it requires extensive coordination of consultants and/or subcontractors.

**DB:** Single point of responsibility for design and construction decreases the potential for conflict between the engineer and constructor (Walewski *et al* 2001; TCRP 2002; Halpin 2006). Although there should be less blaming between designer and constructor (since they are both on the same team and they are jointly responsible to the agency for the success of the project.), instances of disputes between constructor and designer (on the same DB team) were observed during our interviews (TCRP 2009). It is worth mentioning that design-builders may be deterred from submitting claims to owners who have future DB projects to avoid poisoning the well on a qualifications based selection system (QBS) by making the owner angry with a claim.

**Summary**

This section covers two important issues not directly addressed in other sections. Both of these issues are about relations between parties involved in a project. Construction claims and adversarial relation can hamper project success and distract the owner’s focus from project success and quality to dispute resolution.

**Choose the Most Appropriate Project Delivery Method**

The pro/con analysis is not deterministic or judgmental. It only describes the advantages and disadvantages of delivery methods in dealing with each of the pertinent issues discussed. This in turn helps identify strengths and weaknesses of each delivery method in coping with important factors that can affect project goals. This analysis provides a
broad picture of the issues affecting project delivery methods and develops a basis for a decision system. The advantages or disadvantages listed are not absolute and should be considered in comparison with the competing delivery methods.

As mentioned early in this Chapter (Project Goals and Success Factors: Owner’s Perspective), the project scope and goals are playing very important role in project delivery method selection. So any attempt to select an appropriate delivery method should take into account these factors. A descriptive summary that includes only the key variables and provide a “snapshot” of the project scope at the time in which the project delivery decision is selected is sufficient. It serves to communicate the important project characteristics to the decision makers and also to document the project scope for the delivery decision report.

Research and practical experience have shown that the definition of project goals is a key success factor in the project delivery decision (TCRP 2009). Project goals may have different degrees of importance for the project owner. Some owners may accept some shortcomings in a number of goals in order to achieve to the more important ones. Owners need to determine their expectation of their projects and define the project goals along with the scope of work. A summary description of project accompanied with a ranked list of project goals helps the decision makers focus on the main priorities of the project and select a project delivery method that can best facilitate the achievement of those goals.

The analytical decision making process proposed in this chapter is based on the aforementioned 24 pertinent issues. The process consists of several tasks. It first requires
the decision makers to develop a project description and a list of ranked project goals. Then it checks some factors that may eliminate some of the delivery methods from further consideration. The remaining delivery methods then are evaluated based on the aforementioned pertinent issues. The key here is to remember that those issues (just like the project goals) do not have similar importance. The difference between the importance of these issues should be always considered by the decision makers. The definition, advantages and disadvantages of each issue builds the environment in which the decision makers should select an appropriate delivery method. These potential advantages and disadvantages must be examined in the context of each individual project. Variations in the project characteristics, the people involved, and the processes in use by the agencies will determine if these potential issues are actual advantages or disadvantages for a particular project. This validated set of issues serves as a checklist in decision making. It is based on the interviews and literature and shows the state of practice and is requisite for the problem at hand. In other words, a decision maker can be relatively assured that by incorporating these issues in decision, there is not any important factor left out.

The advantages and disadvantages of each delivery method with respect to each one of the issues as presented above is sufficient for understanding the performance of different delivery methods; however, they may not be clear enough for decision makers. One way to better illustrate these points is to divide the statements into two groups of “advantage” and “disadvantage” and put them in tables. For example, if a delivery method is facilitating the use of DBEs, this issue is an “advantage” for that delivery method and if it is making it difficult for the owners to meet the DBE participation goals, then DBE participation should be considered as “disadvantage” for that delivery method. After
reviewing all the issues and filling the relevant tables, one can decide which delivery method possesses more important advantages and whether or not there is a clear trend towards the selection of one delivery method. A sample of these tables and how a descriptive advantage/disadvantage analysis converts to a tabular format is illustrated in the following figure.
### DESIGN-BID-BUILD

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>☐ Costs are known at bid time, before construction begins.</td>
<td>☐ Construction costs are not fixed (or locked in) until design is 100% complete.</td>
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<tr>
<td>☐ Project can benefit from low bid procurement.</td>
<td>☐ Constructability advice and contractor innovations are not available to save cost until post bid.</td>
</tr>
<tr>
<td>☐ Project can benefit from unit price bidding because quantities are defined prior to procurement.</td>
<td>☐ The DBB process is prone to change orders and cost growth after award.</td>
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### CONSTRUCTION MANAGEMENT AT RISK

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>☐ CMR can be used in conjunction with a GMP pricing structure, which can be useful in negotiating and controlling costs.</td>
<td>☐ If multiple bid packages are used, the overall project cost could grow if later bid packages cost more than estimated.</td>
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<tr>
<td>☐ If open book pricing can be used, all costs will be known by the owner.</td>
<td>☐ If a GMP pricing structure is used, owners may have some difficulty in negotiation.</td>
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<tr>
<td>☐ Costs will be known earlier when compared to DBB.</td>
<td></td>
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<tr>
<td>☐ Early constructor involvement or construction advice can lead to cost savings through value engineering and constructability reviews.</td>
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### DESIGN-BUILD

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>☐ If a lump sum pricing structure is used, costs will be fixed early in the project development process.</td>
<td>☐ If a lump sum pricing structure is used, constructors must develop prices before plans are 100% complete and therefore must assume some risk in pricing.</td>
</tr>
<tr>
<td>☐ DB has been shown to have lower average cost growth than DBB or CMR.</td>
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**Figure 4.4. Tabular Illustration of Advantage/Disadvantage Analysis for “Cost”**

The best way to get a comprehensive picture of this analysis is to categorize the performance of each delivery method with respect to each issue and then summarize them in a table. One row of a summary table related to cost (issue number 2) is illustrated in Figure 4.5.
### Figure 4.5. Cost Advantages/Disadvantage Analysis Summary

It is important to remember that there should be no rating or counting involved in this analysis. One can not base his decision on the number of times one delivery method has become “most appropriate delivery method”; it is clear that these issues do not have a similar importance so counting the most appropriate symbols or giving weights will be misleading. The decision makers should find some trends in this tier. They need to look at the big picture and check if there is any delivery method with several advantages and minimal disadvantages with respect to important issues. If no such delivery method is found at this tier, the decision makers should follow up with tier two. The viable options that have passed the “go/no go” step of this tier will be the candidates in tier two (Figure 4.6). Following tier one even when it does not end up with a single delivery method helps the decision makers eliminate those options that are impossible for the project based on “go/no go” parameters. It also helps them understand the performance of these delivery methods in the framework of 24 critical issues.
Figure 4.6. Tier 1 Flowchart: An Analytical Approach for Conventional PDM Selection

The analytical approach in general has a shortcoming: the advantages and disadvantages are considered to have a similar level of importance (Golden et al 1989). The analytical approach suggested in TCRP guidebook (2009) has the same shortcoming. Using a table similar to Table 4.5 and trying to find a trend in this table implicitly assumes similar importance for all of the issues. Even the authors have mentioned that the factors and their pros and cons are considered to have similar importance.
### Table 4.5. Project Delivery Method Advantage/Disadvantage Summary

<table>
<thead>
<tr>
<th>PROJECT DELIVERY METHOD ADVANTAGE/DISADVANTAGE SUMMARY</th>
<th>DBB</th>
<th>CMR</th>
<th>DB</th>
<th>DBOM</th>
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<tr>
<td><strong>Project Level Issues Rating</strong></td>
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<td>1. Project Size</td>
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<td>2. Cost</td>
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<td>3. Schedule</td>
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<td>4. Risk Management</td>
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<td>5. Risk Allocation</td>
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<td>6. LEED Certification</td>
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<td><strong>Agency Level Issues Rating</strong></td>
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<td>7. Agency Experience</td>
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<td>8. Staffing Required</td>
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<td>9. Staff Capability</td>
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<td>10. Agency Goals and Objectives</td>
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<td>11. Agency Control of Project</td>
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<td>12. Third Party Agreement</td>
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<td><strong>Public Policy/Regulatory Issues Rating</strong></td>
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<td>13. Competition</td>
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<td>14. DBE Impacts</td>
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<td>15. Labor Unions</td>
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<td>16. Fed/State/Local Laws</td>
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<td>17. FTA/EPA Regulations</td>
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<td>18. Stakeholder/Community Input</td>
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**Life Cycle Issues Rating**

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<td>19. Life-Cycle Costs</td>
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<td>20. Maintainability</td>
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<td>21. Sustainable Design Goals</td>
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<td>22. Sustainable Construction Goals</td>
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**Other Issues Rating**

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<tr>
<td>23. Construction Claims</td>
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<td>24. Adversarial Relationships</td>
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<td>Other</td>
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**Key:**
- ● Most appropriate delivery method
- ○ Appropriate delivery method
- ○ Least appropriate delivery method
- X Not Applicable (discontinue evaluation of this method)
The importance of considering the difference between the importance of the 24 critical issues cannot be emphasized more in this dissertation. The proposed method in this dissertation suggests that the owner reviews the advantages and disadvantages of PDMs but the decision should not be solely based on the trend found in a summary table. The pro-con analysis should only be considered as a checklist for the decision makers so that they take into account all the aspects of the critical factors. If the owner finds that the analysis does not provide a clear result, it is highly recommended that the second tier be applied. Tier 2 has the capability of clearly distinguishing between the importance of the factors considered in the decision making.

A main advantage of performing the advantage/disadvantage analysis is to educate the decision makers. Defining a set of 24 critical factors and providing the decision makers with a complete analysis of advantages and disadvantages of each PDM with respect to these factors sets the stage for an objective decision. However, due to the nature of the analysis in Tier 1 there is a high probability that the decision can not be solely made based on the results of this tier. The decision makers may not agree upon a trend and superiority of one option over the others. The interpretation of the results may vary based on the decision makers’ subjective judgments. Therefore, it is recommended that the decision makers use the second tier which can better distinguish between the PDMs.

**Conclusion**

This chapter introduced the first tier of a three tier approach for project delivery method selection among conventional methods, *i.e.* DBB, DB, and CMR. The 24 pertinent issues were introduced in this chapter and the advantage/disadvantage of each delivery method with respect to every one of those issues was analyzed. This analysis assists the decision
makers to clarify the scope and critical factors of project delivery method selection. In order to facilitate this analysis it was suggested to categorize the important points and use tabular illustrations. It was emphasized that the pertinent issues are not of the same importance and any counting or weighting in this analytical approach would be misleading. If the decision makers do not come to an agreement on a single delivery method, they need to study the viable options one step more and go to Tier 2 which is explained in detail in the following chapter.

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6 These tables and flowcharts are available in TCRP Guidebook (TCRP 2009)
Chapter 5. Multi-Criteria Decision Approach (Tier 2)

Introduction

As mentioned in Chapter 3, the decision of project delivery method selection includes several factors from risk and cost to sustainability and maintainability of the project. A comprehensive set of critical factors were introduced in Chapter 4. Those issues build a requisite model and encompass all the aspects of project delivery method selection for a transit project. Chapter 4 also introduced a simple analytical approach that can help the owners select the most appropriate delivery method from DBB, DB, and CMR. If a clearly superior delivery method is not found after going through the analytical approach, the owner should apply Tier 2 which applies multi-attribute decision tools. This Chapter introduces two major methods of weighted matrix and Analytic Hierarchy Process (AHP). The procedures to follow in each of the two decision aid tools are explained and a hierarchy of critical factors is constructed based on the critical factors. Also consistency in weighting the factors is discussed to make sure that the weights given to the critical factors are reasonable.

As mentioned in Chapter 4, there is no mechanism in Tier 1 that can clearly distinguish between the importance (or weight) of the pertinent issues. This was done on purpose to ensure that the user of the system does not discard less critical factors in their analysis and risk ignoring the combined effect of a number of secondary critical issues. Contrary to Tier 1, Tier 2 uses a multi-criteria decision making approach. The owner of a transit project can choose either the weighted matrix or AHP as a decision aid tool. In practice, all approaches to multi-criteria decision making explicitly or implicitly use the concept of
relative importance (weight) of criteria. These weights in multi-criteria decision tools express the difference in the level of importance of one criterion in comparison to the other criteria in the set of criteria (Chang 2004).

Independent from the decision aid used, most of the research efforts in this area so far, have a common flaw which is providing a set of weighted factors to the decision makers. A major part of these research efforts has been dedicated to finding these weights and trying to find a consensus among the professionals. This approach has two philosophical errors:

1) The decision makers rely on the pre-determined weights and use them as if they are always true while they are simply based on the subjective judgment of a small (or in the best case, a medium size) group of professionals. This dependency may make the owners forgo the review phase of project goals and advantages/disadvantages of PDMs; thus, a comprehensive understanding of the relation between different PDMs performance and project goals will not be achieved.

2) Each project is unique in its scope, barriers, risks and opportunities. Hence, the performance of PDMs should be analyzed with regards to each project under consideration. Caution should be practiced for any attempts to generalize a decision support system tool that can be applied in various cases. Although the researchers have tried to minimize the effect of inherent differences in project characteristics by limiting the project types (such as Oyetunji (2001) that specifies his methodology to building projects), the uniqueness of projects is still neglected in these research efforts. Availability of a weighted set of factors will facilitate the decision process at the cost of
neglecting the effect of each project on these weights. This issue is even more important in transit projects where the location, type, size, and risks of the projects vary widely.

Based on the two aforementioned reasons, this dissertation does not provide a weighted set of factors. Moreover, the owner can select the critical factors and there is no obligation in using a set of pre-determined factors with fixed weights. These factors may be chosen from the set of 24 issues introduced in previous chapter, they can be some of project goals and objectives, or a combination of the issues and goals. To assist the decision maker, the frameworks and procedures of a weighted matrix approach and AHP are comprehensively explained and the mathematical methods of consistency in weighting factors are introduced.

**Weighted Matrix Procedure**

Weighted matrix is a simple approach that can be applied to almost any multi-attribute problem. The application of this approach in project delivery method selection is well documented in the literature. Oyetunji and Anderson (2006) developed a comprehensive decision support system based on weighted matrix approach that was aimed to be applied in building projects. (Please refer to Available Decision Support Systems for PDM Selection in Chapter 3). The recent Transit Cooperative Research Program Guidebook (TCRP 2009) also uses the weighted matrix as its decision aid tool for project delivery method selection because it is “founded upon successful delivery decision tools developed by academics and professionals over the past 20 years”. The main reason why it was preferred over other successful decision aid tools was its simplicity while it yields consistent and robust results if applied properly.
The weighted matrix approach has a simple procedure. The user should first define a set of critical factors that affect the decision. Then these factors should be weighted based on their importance and participation in the achievement of total project goals. The third step is to score the available alternatives with respect to each of these factors. Then the score of each alternative should be multiplied by the weight of that factor. The total score of each alternative is the summation of the product of the weights and scores (Figure 5.1).

Figure 5.1. Weighted Matrix Approach for Conventional PDM Selection
To define the critical factors for weighted matrix, the owner should review the project goals and any additional critical issues examined in the analytical decision process. This helps the owner identify the most important factors for the matrix. The number of factors should not exceed 7 because of difficulty in keeping the consistency of weights (TCRP 2009). The factors can be selected from the set of 24 issues introduced in Chapter 4 or the owner can combine them with some of the project goals and define new factors (Figure 5.2). Caution should be exercised during the development of critical factors to make sure that they do not have overlaps or interdependency, no important factor is left out of the set, and the critical factors are defined concisely and clearly. A review of the advantages/disadvantages analysis of delivery methods will also assist the owner in scoring the delivery methods. Since the scores will be subjective, the owner should document the reasons for the scores. In the same vein, a final review of each of the values in the matrix (weights, scores and the total scores) is strongly recommended to determine if the values are logical and defensible on the basis of their professional judgment as the weighted matrix system is based on subjective evaluation of options. Some of the researchers recommend a sensitivity analysis (Chang 2004) so that the owner can precisely examine the effect of weights and scores on the final choice.

Figure 5.2. Weighted Matrix Selection Factor Development
An example of a set of critical factors to be used in a weighted matrix can be as the following:

- Cost not to exceed XXX,
- Project complete by YYY,
- Minimize the number and dollar value of construction claims,
- Minimize staffing requirements during design and construction,
- Minimize the number of new employments and/or hired consultants,
- Facilitate the achievement of LEED certification.

There are several procedures introduced in the literature for weighting the factors in a method like weighted matrix (e.g. Delphi method, pairwise comparison, rank order centroid, and ratio method) that are explicitly discussed in the following parts of this chapter. However, it is important to mention that the proposed decision support system does not intend to provide a set of pre-determined weights to be used in weighted matrix approach. The owners need to select one of the procedures mentioned above and come up with their own set of weights that reflect the nature and scope of the project under consideration.

Regardless of the weighting procedure chosen, the owner should follow the following steps in the process of weighting the factors:

- List the selection factors in rank order from their highest to the lowest influence on project goals.
- Include a minimum of four (4) and a maximum of seven (7) factors.
• Weight the factors (from 1 to 100) according to their influence on project success.

• Avoid equal weighting of factors.

• Remove any factors with a value of less than five (5) of the 100 points and redistribute points. (TCRP 2009)

Equal factor weightings are not recommended because distinguishing the importance between factors is necessary for the decision process. Additionally no single factor should have a point value of less than five (5) because it will not have an influence on the final decision and may in fact make the selection more difficult.

Each of the delivery methods has an influence on the selection factors. The decision makers should translate this influence into a score to arrive at a decision. The following table assists the owners in scoring each delivery method as they relate to the selection factor. Consideration should be given to the relative scores for each delivery method to ensure consistency.
Table 5.1. Project Delivery Scoring Scale (adapted from Saaty 1990)

<table>
<thead>
<tr>
<th>SCORE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>The evidence that the delivery method positively aligns with the project objective or issue is of the highest possible order of affirmation.</td>
</tr>
<tr>
<td>8</td>
<td>The delivery method strongly aligns with the objective or issue and is demonstrated in practice. There is a slight risk that the objective or issue may not be beneficial.</td>
</tr>
<tr>
<td>6</td>
<td>Experience and judgment point to the delivery method strongly aligning with the objective or issue. There is a mild risk that the objective may not be beneficial.</td>
</tr>
<tr>
<td>4</td>
<td>Experience and judgment slightly points to the delivery method aligning with the objective or issue. There is a strong risk that the objective will be negatively affected.</td>
</tr>
<tr>
<td>2</td>
<td>There is little benefit to applying the delivery method for this goal or objective. There is a strong likelihood that the object will not be achieved.</td>
</tr>
<tr>
<td>9,7,5,3,1</td>
<td>Intermediate values between two adjacent judgments.</td>
</tr>
</tbody>
</table>

The results should be put together in a table like Table 5.2. All the critical factors should be listed on the left column with their given weights in the next column.
Table 5.2. Weighted-Matrix Template

<table>
<thead>
<tr>
<th>Selection Factor</th>
<th>Factor Weight</th>
<th>DBB Score</th>
<th>DBB Weighted Score</th>
<th>CMR Score</th>
<th>CMR Weighted Score</th>
<th>DB Score</th>
<th>DB Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 4 to 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At this point, choosing the appropriate delivery method is simply a matter of reviewing the total scores and making the project delivery decision. Since the factor weighting and the scores are subjective, the owner should review the totals and confirm that they are logical and defensible. A sensitivity analysis is also recommended to check the effectiveness of any changes in the weight of each factor or score of each delivery method on the final decision. As the scores and weights are all subjective, a slim difference between the total score of two rivals is not a solid ground for the final selection. If the decision makers do not observe a distinguishing difference between the performances of two delivery method, it is recommended that they eliminate the delivery method with the lowest total score and apply the final tier of this decision support system and further evaluate the remaining two options.
AHP Procedure

An alternative approach to the weighted matrix approach described above is the Analytic Hierarchy Process (AHP). The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment. The AHP methodology compares criteria, or alternatives with respect to a criterion, in a natural, pairwise mode (Forman et al 2001). “AHP is used to derive ratio scales from both discrete and continuous paired comparisons in multilevel hierarchic structures.” (Saaty et al 2001) “A hierarchy is an abstraction of the structure of a system to study the functional interactions of its components and their impacts on the entire system.” (Saaty 1980).

The weighting matrix resulting from pairwise comparison consists of elements like \( a_{ij} \) which shows the preference of item \( i \) over item \( j \) (or ideally \( w_i/w_j \)). So the resulting matrix would be similar to:

\[
A = \begin{bmatrix}
\frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\
\vdots & \ddots & \vdots \\
\frac{w_n}{w_1} & \cdots & \frac{w_n}{w_n}
\end{bmatrix}.
\]

This matrix is a positive, consistent and reciprocal matrix if \( a_{ij} = 1/a_{ji} \) and \( a_{ij} \times a_{jk} = a_{ik} \) (\( i, j, k = 1, \ldots, n \)).

If \( w = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \) is the matrix of weights for the \( n \) items under consideration, then ideally, \( Aw = nw \). In practice, the \( a_{ij} \) elements of the matrix are not based on exact measurements and the ratio of \( w_i/w_j \) but on subjective judgment (Saaty 1980). In this case the problem is to find the answer for the following equation to get the priority vector (w): \( Aw = \lambda_{max}w \). \( \lambda_{max} \) is the maximum eigenvalue of \( A \) and will be used to check the consistency of the matrix. The reason why \( \lambda_{max} \) is chosen for consistency test will be explained below.
AHP is a decision aid tool that has been used by researchers for similar applications (Al Khalil 2002; Ababtain et al 2003; Mahdi et al 2005; Mafakheri et al 2007). Most of the applications found in the literature involve development of a set of factors categorized in several levels with pre-determined weights. The owner is left with the last part of the process which is scoring the alternatives. This dissertation, however, for the reasons mentioned at the beginning of the chapter does not give pre-determined weights to the factors.

The AHP helps the decision maker decompose a complex problem into its elements. This way a hierarchy of several categories and sub-categories is developed. The AHP uses pairwise comparison to derive local priorities of factors in each category. These local priorities are then multiplied by the weight of the upper level category and determine the global weight of each factor. It is recommended that the factors being compared should not have a very different level of importance (not differ by more than an order of magnitude in any group), otherwise there will tend to be larger errors in judgment (Forman et al 2001). Also it is important not to base the judgments of the priorities of the elements in a hierarchy on lower level elements (Forman et al 2001). For example the schedule should not be given an extraordinarily higher weight because a biased decision maker knows that this way he is increasing the chance of DB to get selected.

In order to apply AHP to the problem, these steps should be followed:

- The critical factors should be identified with their respective subdivisions. The main groups of factors are the five categories defined in Tier 1 (project level,
agency level, etc.) and their subdivisions are the 24 pertinent issues defined in analytical decision process of Tier 1 (Figure 5.3).

- The alternatives should be identified. The alternatives in this case are DBB, DB, and CMR.

- A hierarchy for the problem should be developed in which the project goals are on top, the main groups of criteria (project level, agency level, etc.) are listed in the second level, the factors come in the third level and at the bottom are the alternatives (Figure 5.3).

- Using pairwise comparison, all the factors of each group should be weighted based on their relative importance in their respective category. For example the “schedule” should get a weight in “project level” category based on its importance in that category.

- The 5 categories should get a weight based on their role in the achievement of project goals using the same method of pairwise comparison.

- The alternatives should be scored with respect to every factor using pairwise comparison.

- The total score of each alternative (PDM in this case) is the sum of the total products of weights and scores.

- At last the consistency of the assigned weights should be checked.
The weighting matrix is not always perfectly consistent. Inconsistency of the weights in a pairwise comparison has two major sources: the decision maker and the method. The decision maker cannot perfectly express preferences in a consistent way. The method also has an inherent inconsistency because of the use of fixed scales in comparing the pairs (Temesi 2006). The consistency of the resulting matrix should be checked. Saaty and others (Saaty 1980; Saaty et al 2001) have suggested the following steps for checking the consistency ratio (CR) by calculating the Consistency Index (CI) and comparing it with a fixed value of Random Index (RI):

\[ CI = \frac{\lambda_{max} - n}{n - 1} \]

in which \( n \) is the matrix size and \( \lambda_{max} \) is the maximum eigenvalue calculated using the following procedure (Al Harbi 2001):

- Multiply each value of each column of the matrix by the corresponding relative priority value.
- Add up all the columns resulting from the previous step.
- Divide each element of the column (weighted sums) by the corresponding priority value.
- Calculate the average of the above values. Let \( \lambda_{max} \) be the average.

The RI is given in the following table (Lane et al 1989). The consistency ratio (CR) is calculated as \( CR = CI / RI \). Any matrix with a consistency ratio below 0.10 is usually considered as acceptable because this level of inconsistency does not severely affect the results (Al Harbi 2001).
Table 5.3. Random Index Quantities Based on the Size of the Pairwise Comparison Matrix

(Saaty 1980)

<table>
<thead>
<tr>
<th>Size of matrix</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
</tr>
</tbody>
</table>

Theoretical background of consistency test

If \( a_{ij} = \frac{w_i}{w_j} \) for \( i, j = 1, ..., n \) are the numbers shaping the pairwise comparison matrix \( A \), then \( A \) is a consistent and reciprocal matrix if \( a_{ij} = 1/a_{ji} \) and \( a_{ij} \times a_{jk} = a_{ik} \) \((i, j, k = 1, ..., n)\). Assume that we have an equation like \( Ax = y \) where \( x = (x_1, ..., x_n) \) and \( y = (y_1, ..., y_n) \). It can be written as \( \sum_{j=1}^{n} a_{ij}x_i = y_i \). At the same time from consistency definition the following equation holds: \( a_{ij} \frac{w_j}{w_i} = 1 \). So \( \sum_{j=1}^{n} a_{ij}w_j \frac{1}{w_i} = n \) or \( \sum_{j=1}^{n} a_{ij}w_j = nw_i \) for \( i = 1, ..., n \). This is equivalent to \( Aw = nw \). As mentioned above, the decision makers do not (and mostly can not) act ideally in determining \( a_{ij} \) and they are not necessarily equal to \( a_{ij} = 1/a_{ji} \). In this case \( Aw = nw \) does not hold anymore but if \( Ax = \lambda x \), based on matrix theory \( \lambda_1, ..., \lambda_n \) are the numbers satisfying that equation and are the eigenvalues of \( A \) and if \( a_{ii} = 1 \), then \( \sum_{i=1}^{n} \lambda_i = n \). So in an ideal consistent matrix all the eigenvalues are zero except for one which is equal to \( n \). In other words in a perfectly consistent matrix \( \lambda_{max} = n \). Also based matrix theory it is known that “a change in \( a_{ij} \) of a positive reciprocal matrix by small amount will change the eigenvalues of that matrix by small amounts” (Saaty 1980). Combining these two facts shows that if
$A$ is consistent, a small variation in $a_{ij}$ keeps the largest eigenvalue ($\lambda_{max}$) close to $n$ and the rest of the eigenvalues close to zero. So if $A$ is the matrix of pairwise comparison and $w$ is the priority vector, the problem to solve would be $Aw = \lambda_{max}w$. Also as mentioned the difference between $n$ and $\lambda_{max}$ shows the deviation from perfect consistency. In order to have a benchmark for measuring the consistency, the random index (R.I.) was generated and introduced by Saaty (1980). R.I. is simply an average of consistency index in a sample size of 500. Each matrix is generated at a random basis. In other words $a_{ii} = 1$ and $a_{ij} (i > j)$ is a random number and $a_{ji} = 1/a_{ij}$. The average for each matrix size is given in Table 5.3. The methodology is explained in more details in Saaty (1980).

Example

To better illustrate the procedure of AHP, a complete example of applying AHP to the problem of project delivery method selection is provided here. The first steps were done in the previous chapter (Chapter 4 - Analytical Delivery Decision Approach) and a series of factors were defined and categorized in 5 groups. The hierarchy is constructed based on that set of factors as illustrated in the figure below.
Let us assume that the project goals are as follows:

1) Compress Project Schedule,

2) Deliver project at or below budget,

3) This must be an affordable, appealing mode of transportation for riders,

4) Minimize Disruption to the public,

5) All facilities (tunnels, systems, stations, buildings) must be sustainable (according to the relevant codes and standards) with minimized O&M requirements and costs.
These goals will be at Level 1 of the hierarchy. Based on the goals established and listed in the first level, the main groups of factors that are at the second level should be weighted. For example, most of the goals listed above are related to project level group. So it should get a higher weight in comparison with agency level or other groups. At the same time it is assumed that the decision maker has not been able to distinguish between the significance of the role of “life cycle” group and “other” group so its relevant $a_{ij}$ is given as 1. The following table shows their weights. As an example, it is assumed that the weight of “project level” issues is twice the weight of “agency level issues and three times the weight of “public regulatory” issues. It should also be mentioned that the CR for each matrix is calculated following the procedure explained above (Kwiesielewicz et al 2004).

**Table 5.4. Weights for Second Level of Hierarchy of AHP Example**

<table>
<thead>
<tr>
<th></th>
<th>project level</th>
<th>agency level</th>
<th>public regulatory</th>
<th>life cycle</th>
<th>Other</th>
<th>total</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>project level</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>13</td>
<td>0.366204</td>
</tr>
<tr>
<td>agency level</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>10.5</td>
<td>0.29578</td>
</tr>
<tr>
<td>public regulatory</td>
<td>0.333</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5.833</td>
<td>0.164313</td>
</tr>
<tr>
<td>life cycle</td>
<td>0.3333</td>
<td>0.333</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>3.1663</td>
<td>0.089193</td>
</tr>
<tr>
<td>Other</td>
<td>0.25</td>
<td>0.25</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0.084509</td>
</tr>
</tbody>
</table>

CR 0.023

\[
\begin{bmatrix}
1 \\
0.5 \\
0.333 \\
0.25
\end{bmatrix}
+ 0.366204
\begin{bmatrix}
2 \\
1 \\
0.5 \\
0.25
\end{bmatrix}
+ 0.29578
\begin{bmatrix}
3 \\
2 \\
0.333 \\
0.333
\end{bmatrix}
+ 0.164313
\begin{bmatrix}
3 \\
2 \\
0.5 \\
0.5
\end{bmatrix}
+ 0.089193
\begin{bmatrix}
3 \\
2 \\
1 \\
1
\end{bmatrix}
+ 0.084509
\begin{bmatrix}
4 \\
4 \\
1 \\
1
\end{bmatrix}
= \begin{bmatrix}
2.056 \\
1.413 \\
1.781 \\
0.476 \\
0.421
\end{bmatrix}
\]
\[
\frac{2.056}{0.366} = 5.617, \quad \frac{1.413}{0.295} = 4.789, \quad \frac{0.781}{0.164} = 4.762, \quad \frac{0.476}{0.089} = 5.348, \quad \frac{0.421}{0.084} = 5.011
\]

\[
\lambda_{\text{max}} = \frac{(5.617 + 4.789 + 4.762 + 5.348 + 5.011)}{5} = 5.105
\]

\[
CI = \frac{(\lambda_{\text{max}} - n)}{n - 1} = \frac{(5.105 - 5)}{5 - 1} = 0.026, \quad RI = 1.12 \quad CR = \frac{0.026}{1.12} = 0.023
\]

Then the factors in each group should be weighted using pairwise comparison. Schedule is the most important factor in this group because one of the project goals is to compress the schedule. Cost is also an important factor of this group because another project goal is to “deliver project at or below budget”. The following tables are the results of these comparisons. As an example, the weight of “project size” is only 0.2 of “schedule” and 0.25 of “cost”.

**Table 5.5. Weights for Third Level of Hierarchy of AHP Example**

<table>
<thead>
<tr>
<th>Project Level</th>
<th>size</th>
<th>schedule</th>
<th>Cost</th>
<th>risk allocation</th>
<th>risk mgmt</th>
<th>LEED</th>
<th>total</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>1</td>
<td>0.2</td>
<td>0.25</td>
<td>0.33</td>
<td>0.33</td>
<td>2</td>
<td>4.11</td>
<td>0.061</td>
</tr>
<tr>
<td>Schedule</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>24</td>
<td>0.3563</td>
</tr>
<tr>
<td>Cost</td>
<td>4</td>
<td>0.5</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>21.5</td>
<td>0.3192</td>
</tr>
<tr>
<td>risk allocation</td>
<td>3</td>
<td>0.25</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>7.5</td>
<td>0.1113</td>
</tr>
<tr>
<td>risk mgmt</td>
<td>3</td>
<td>0.25</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>7.5</td>
<td>0.1113</td>
</tr>
<tr>
<td>LEED</td>
<td>0.5</td>
<td>0.125</td>
<td>0.125</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>2.75</td>
<td>0.0408</td>
</tr>
</tbody>
</table>

CR 0.0416
Then each project delivery method should be scored with respect to every one of the 24 factors of Level 3. The pairwise comparison is used for this step. As an example, DB is
given a weight of 5 compared to DBB and a weight of 2 compared to CMR for “schedule.” The results would be 24 tables like the following which is for “schedule”:

<table>
<thead>
<tr>
<th>Schedule</th>
<th>DBB</th>
<th>DB</th>
<th>CMR</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBB</td>
<td>1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.015784</td>
</tr>
<tr>
<td>DB</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0.083565</td>
</tr>
<tr>
<td>CMR</td>
<td>2</td>
<td>0.333</td>
<td>1</td>
<td>0.030947</td>
</tr>
</tbody>
</table>

The total score of each project delivery method is the summation of the product of their scores with the global weight of each of the 24 factor. The results of this example are illustrated in the table below:

Table 5.6. The Final Results of the AHP Example

<table>
<thead>
<tr>
<th>DBB</th>
<th>DB</th>
<th>CMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.346206</td>
<td>0.368034</td>
<td>0.2809</td>
</tr>
</tbody>
</table>

All the CRs calculated are less than or equal to 0.1 which satisfies the consistency condition of AHP and one can trust the final results of comparison between DBB, DB, and CMR (Al Harbi 2001). As it can be seen the difference between the DBB and DB is not significant enough to conclude the process of PDM selection. In this case the PDM with the lowest score is eliminated and the two remaining options are selected for further studies in Tier 3.
Weighted Matrix or AHP?

Understanding and communicating a concise set of project goals is one of the most important elements in selecting an appropriate project delivery method (TCRP 2009). The definition of project goals is a key success factor in not only the project delivery decision, but also the development of procurement documents and the administration of a project. It is the performance goals (e.g. time, cost, quality, maintainability, and sustainability) that typically drive the project delivery decision. These goals are used as the foundations of both of the multi-criteria decision tools proposed in this chapter. The pertinent issues defined in the previous chapter along with the project goals constitute the critical factors that should be considered in weighted matrix or AHP. The methods used in these two decision tools to weigh the factors are also similar (except that pairwise comparison was originally used in AHP). One major difference between these two is the level of complexity. AHP requires an in-depth study of factors and categorizing them. It needs a hierarchy to be constructed and several comparisons to be performed so that every factor in a sub-division gets a global weight. Weighted matrix on the other hand does not have any hierarchy and one round of comparison is sufficient to determine the weight of each factor. Accordingly, a less complicated method of weighted matrix would be more appropriate for a guidebook while a more complicated method like AHP would work better in research efforts. It should be mentioned again that increasing the level of complexity, per se, does not make the result of decision making more precise and defensible because the whole decision is based on a series of subjective judgments no matter which decision tool is selected. However, the AHP forces the decision makers to follow a more strict discipline in their thinking and decompose each factor into its
constituents, hence reducing the possibility of overlooking an important issue and hopefully obtaining reasonable results. Another difference is in the number of factors considered. Weighted matrix is not designed to take into account many factors. Its flat structure demands a comparison of all factors at one level. This makes their paired comparison very difficult (if possible).

**Determining the Weights of Selection Factors**

Weighted matrix and AHP decision approach consist of ranking and weighting the short-listed selection factors. While a completely subjective method can be used to assign these weights, many formal procedures have been developed in management science that facilitate this process and makes it more objective. This section describes four such methods that combine subjective and objective methods to arrive at weight values for the key selection factors used in weighted matrix or AHP. These methods have been selected for their simplicity and effectiveness. These methods will help the decision makers develop more consistent and transparent weights. The four methods described here are: (1) Delphi Method, (2) Rank Order Centroid Method, (3) Ratio Method, and (4) Pairwise Comparison Method.

**Delphi method**

The Delphi method is a reliable way of obtaining the opinions of a group of experts on an issue by conducting several rounds of interrogative communications. This method was first developed in the US Air force in 1950’s mainly for market research and sales forecasting. (Chan et al 2001)
This method is basically a communication device which is particularly useful to achieve a consensus among experts given a complex problem. The method consists of repeated solicitations of questions from a panel of experts who are anonymous. The information and ideas of each panel member are distributed among all the panel members in the next round. They can comment on others’ viewpoints and can even use new information to modify their own opinions. Anonymous panel members can change their opinions based on new information easier than regular group meetings and open discussion. A consensus of opinions should be ultimately achieved in this way.

This method will also highlight the areas where panel members have disagreements or uncertainty in a quantitative manner. The evaluation of belief statements by the panel as a group is an explicit part of the Delphi method (Chan et al 2001).

The panel consists of a number of experts chosen based on their experience and knowledge required to solve the problem. As mentioned previously, panel members will remain anonymous to each other throughout the procedure in order to avoid the negative impacts of criticism on innovation and creativity of panel members. The Delphi method should be conducted by a director (facilitator) who has independent communication with each panel member. The director develops a questionnaire based on the problem at hand and sends them to each panel member. Then the responses to the questions and all the comments are collected and evaluated by the director. The director should process the information and filter out the irrelevant content. The result of the processed information will again be distributed among the panel members. Each member receives new information and ideas and can comment on them and/or revise his own previous opinions.
In the context of weighted matrix one can use the Delphi method for giving weights to the short-listed critical factors. In AHP, the Delphi method can be used for giving weight to the factors in each division at each level. The panel members should give weights to each factor as well as their reasoning. In this way, other panel members can evaluate the weights based on the reasons given and accept, modify or reject those reasons and weights in the second round of survey.

For example let us assume that after applying analytical approach by the transit agency, there are still two or more project delivery methods remaining as viable options. The agency has identified the following four factors to be considered in the weighted matrix:

- shortening the schedule
- agency control over the project
- project cost
- competition among contractors

The facilitator should ask the panel members to weight each of the factors while giving their reasons for the weights selected. The facilitator can then work with the collected viewpoints and establish a weight for each factor. One possible approach could be to calculate an average weight for each factor based on responses. If there are large divergences in some responses, the facilitator should study that and comment on those cases. The outcome of this analysis should be distributed to the panel again for further consideration and modification. The facilitator will decide when to stop the process based on the level of consensus desired.
Rank Order Centroid (ROC)

This method is a simple way of giving weight to a number of items ranked according to their importance. The decision makers usually can rank items much easier than giving weight to them. This method takes those ranks as inputs and converts them to weights for each of the items. The conversion is based on the following formula:

\[ W_i = \left(\frac{1}{M}\right) \sum_{n=i}^{M} \frac{1}{n} \]

where \( M \) is the number of items and \( W_i \) is the weight for \( i^{th} \) item. For example if there are 4 items for giving weights, the item ranked first will be weighted \((1/1 + 1/2 + 1/3 + 1/4) / 4 = 0.52\), the second will be \((1/2 + 1/3 + 1/4) / 4 = 0.27\), the third \((1/3 + 1/4) / 4 = 0.15\), and the last has a weight of \((1/4) / 4 = 0.06\). As it is shown in this example, the ROC is simple and easy to follow but it gives weights which are highly dispersed (Chang 2004).

As an example, consider the same factors to be weighted (shortening schedule, agency control over the project, project cost, and competition). If they are ranked based on their importance and influence on decision as 1- shortening schedule, 2- project cost, 3- agency control over the project and 4- competition, their weights would be 0.52, 0.27, 0.15 and 0.06 respectively. These weights almost eliminate the effect of the fourth factor, i.e., competition among contractors.

Ratio Method

Ratio method is another simple way of calculating weights for a number of items. A decision maker should first rank all the items according to their importance. The next step is giving weight to each item based on its rank. The lowest ranked item will be given a
weight of 10. The weight of the rest of the items should be given as multiples of 10. The last step is normalizing these raw weights (Weber et al 1993). This process is shown in the example below. Notice that the weights should not necessarily jump 10 points from one item to the next. Any increase in the weight is based on the subjective judgment of the decision maker and reflects the difference among the importance of the items. Ranking the items in the first step helps in giving more accurate weights.

**Table 5.7. Ratio Method Example**

<table>
<thead>
<tr>
<th>Task</th>
<th>Item</th>
<th>shortening schedule</th>
<th>project cost</th>
<th>agency control</th>
<th>competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Weighting</td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Normalizing</td>
<td>41.7%</td>
<td>33.3%</td>
<td>16.7%</td>
<td>8.3%</td>
<td></td>
</tr>
</tbody>
</table>

Normalized weights are simply calculated by dividing the raw weight of each item over the total weights of all items. For example, normalized weight for the first item (shortening schedule) is calculated as \(\frac{50}{50 + 40 + 20 + 10} = 41.7\%\). Notice that the sum of normalized weights is equal to 100\% \((41.7 + 33.3 + 16.7 + 8.3 = 100)\).

**Pairwise Comparison**

In the pairwise comparison method the decision maker should compare each item with the rest of the group and give a preferential level to the item in each pairwise comparison (Chang 2004). For example if the item at hand is as important as the second one, the
preferential level would be one, and if it is extremely more important, its level should be 10. After conducting all of the comparisons and determining the preferential levels, the numbers will be added up and normalized. The results are the weights for each item. Table 5.1 can be used as a guide for giving preferential level score to an item while comparing it with another one.

The following example shows the application of the pairwise comparison procedure. Referring to the four critical factors identified above, let us assume that shortening the schedule, project cost and agency control of the project are the most important parameters in the project delivery selection decision. Following the pairwise comparison, the decision maker should pick one of these factors (e.g., shortening schedule) and compare it with the remaining factors and give a preferential level to it. For example shortening schedule is more important compared to project cost; in this case it will be given 5 as the level of importance. The decision maker should continue the pair-wise comparison and give weights to each of them. The table below shows the rest of the hypothetical weights and the normalizing process, the last step of the pairwise comparison.
### Table 5.8. Pairwise Comparison Example

<table>
<thead>
<tr>
<th></th>
<th>Shorten the schedule</th>
<th>Project cost</th>
<th>Agency control</th>
<th>Competition</th>
<th>Total</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shorten the schedule</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>20</td>
<td>20/37.2=0.54</td>
</tr>
<tr>
<td>Project cost</td>
<td>1/5</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>10.2</td>
<td>10.2/37.2=0.27</td>
</tr>
<tr>
<td>Agency control</td>
<td>1/6</td>
<td>1/3</td>
<td>1</td>
<td>4</td>
<td>5.5</td>
<td>5.5/37.2=0.15</td>
</tr>
<tr>
<td>Competition</td>
<td>1/8</td>
<td>1/6</td>
<td>1/4</td>
<td>1</td>
<td>1.5</td>
<td>1.5/37.2=0.04</td>
</tr>
</tbody>
</table>

Total = 37.2

Note that Column (5) is simply the sum of the values in Columns (1) through (4). Also note that if the preferential level of factor $i$ to factor $j$ is $n$, then the preferential level of factor $j$ to factor $i$ is simply $1/n$. The weights calculated for this exercise are 0.54, 0.27, 0.15, and 0.04 which add up to 1.0.

### Conclusions

The second tier of the proposed decision support system for selecting a project delivery method from DBB, DB, and CMR is a multi-criteria decision approach. This approach considers a set of critical factors, determines their relative importance in the achievement of project goals and uses them in a structured framework to distinguish between the
performances of each project delivery method. This chapter introduced the weighted matrix and analytic hierarchy process as two well-structured decision tools and studied their application in project delivery method selection. Some examples were provided in this chapter to better illustrate the procedures of these two decision tools. It is possible that at the conclusion of Tier 2 a clear decision cannot be made. In case the total scores of two delivery methods are close, the decision maker should study the performance of those methods with respect to risk allocation of the project. The use of risk analysis for PDM selection is not a very common practice simply because it is expensive and more importantly it will take several weeks to conduct a risk analysis. Therefore, it is recommended that the decision be made at the end of Tier 2. The last tier should be only used if the score of two rival PDMs are so close that the decision maker can not come up with a final decision at this stage.
Chapter 6. Risk Based Approach (Tier3)

Introduction

Risk has a broad definition that can cover several aspects of project but is mainly used to indicate a potentially adverse circumstance with the potential of causing undesired cost growth or time delays. Growing concerns over the delays and cost overruns have increased the importance of risk management and allocation. Because of this, risk allocation and risk management were both included in the list of pertinent issues in Tier 1 of the decision support system. The type of project delivery method will have a profound impact on risk allocation simply because the main vehicle for risk allocation in a project is the contract. Nevertheless, the risks should be allocated to the parties in the best position to control them (Quiggin 2002; Grimsey et al 2002). Also, the consequences of allocating each risk to the receiving party and the proportionality of the cost incurred or charged by the receiving party should be analyzed (Parsons et al 2004).

Risk management is basically making decisions and taking mitigating actions to reduce adverse risks and to realize opportunities. “The process involves preparing an action plan that prioritizes risks, identifies the underlying causes of risk events, and describes ways to change the likelihood of risk events and their potential costs and schedule impacts.” (Parsons et al 2004)

The owner should analyze the risk sharing and risk mitigation mechanisms in different delivery methods while considering risk allocation and risk management as two influential factors. Each project delivery method provides the owner with a unique
structure for risk allocation among the parties involved. An appropriate project delivery method can also lower the total level of project risks by decreasing the number of risk factors and by allocating different risk factors to the parties best able to manage them. As mentioned in Chapter 3, most of the PDM selection methodologies dedicate at least one decision factor to project risk allocation/management. The proposed decision support system in this dissertation, however, goes one step further and develops a risk-based tier that should be used to select the most appropriate PDM. This tier has two main parts: qualitative approach and quantitative approach. Examples are provided in each part to better illustrate the proposed procedures in each part.

Risk Analysis in Transit Projects and PDM Selection Systems

Touran et al (1994) developed a framework for managing risks in the design and construction phase of fixed guideway capital transit projects. They defined risk as “the potential for monetary loss resulting from uncertainty about the project.” Their report covered the financial aspects of transit projects from the owner’s perspective and studies the volatility in the interest rate and escalation. It also provided a checklist for risk identification and reviewed the risk mitigation actions.

Due to cost escalation on large transit projects, since 2002, the FTA has required that each “New Starts” project undergo a formal risk-based cost estimate (TCRP 2009). Specific requirements for these risk assessments are provided in FTA guidance documents. As an example, the current FTA guidance on risk assessment is PMO Operating Procedures No. 40, (Risk Management Products and Procedures 2008) which is aimed to “support FTA programmatic decisions made under uncertainty in a project delivery environment where transit projects are complex and inherently risky.” It
establishes a baseline for evaluating the reliability of the owner’s project cost estimate and its components given the various elements of uncertainty associated with it.

Parsons et al (2004) prepared a guide for risk analysis and methodologies to be used in FTA projects. This guide provided some useful definitions and introduced the qualitative and quantitative approaches to risk assessment. It also gave guidance for risk allocation and risk management in transit projects. The risk analysis process introduced has six steps (Figure 6.1) which will be explained in the following parts of this chapter.

![Figure 6.1. The Risk Analysis Process of FTA Guidebook](image)

Molenaar (2005a) introduced a risk-based method for highway projects cost estimate mainly for highways. Molenaar’s paper describes the cost estimating validation process (CEVP) methodology for stochastic estimating of highway projects. It starts with validating the base costs (project costs with no contingency incorporated into them). Total project costs will be the sum of the base costs and risk costs. The risk identification will be done in a workshop by identifying major risk factors and quantifying their impact by estimating the probability of occurrence and their impact. These data is then used in a Monte Carlo simulation which will result in a probability density function (pdf) for the project budget (Molenaar 2005a; Reilly et al 2004).
Selection of an appropriate project delivery method in Australia (Queensland) is stated to be based on the risk assessment, experience and knowledge of the staff about different PDMs, further considerations and preferences of the owner, risk profile and scale of the project (Queensland Government Department of Main Roads 2005).

Tsamboulas et al (2000) suggest a risk-based methodology to assess the attractiveness of transportation infrastructure projects to private financing. They divide the project risks into five groups: 1) market risks, 2) political risks, 3) financial risks, 4) environmental risks, and 5) technical risks. Then the project risks are evaluated from the viewpoint of a private sector investor whose goal is mainly maximizing his financial benefits. The proposed methodology uses the pairwise comparison to give weights to risk factors after they are allocated to different parties involved in the project. The overall ranking of the project shows whether or not it is a good candidate for investment. Although the method applies the very basic concepts of risk allocation and pairwise comparison, it is developed to evaluate the projects from an investor’s viewpoint in a PPP framework; it can not be used to compare conventional project delivery methods.

Gordon (1994) considers the risk aversion factor among the PDM evaluation factors. Moreover, he believes that the owner should assess the risks involved in the project and select the most appropriate project contract (i.e. payment method such as lump sum, GMP, and cost plus) based on risk allocation. However, the main risk factor considered in his study is the risk of cost overrun. Gordon states that “a balancing of the risk should be sought between the owner and his contractor or designer in order to utilize the incentive value of bearing risk while minimizing a contingency charged for accepting the risk.” Al-Hazmi (2000) considers two major risks of time overrun and financial risks
among the influential factors of an AHP model for PDM selection. Mahdi et al (2005) dedicates one segment of their AHP model to risk and include both risk allocation and risk management in that part as two significant factors in selecting an appropriate PDM.

Oyetunji et al (2006) take the risk of finance into account in their decision support system while some other factors in their system have some sort of uncertainties and risks in them (e.g. local conditions in project site). Mafakheri et al (2007) have a risk factor among the decision criteria in their AHP model.

All of the aforementioned decision support systems for PDM selection have considered risk factor along with other influential factors such as schedule or cost. Some of the other factors considered in these systems are technically related to project risk allocation and management such as owner’s control over the project or adversarial relations between the parties involved. This dissertation has proposed a system that considers risk at two levels: first it is studied as a separate (not necessarily independent) factor along with 23 other factors in Tier 1 and then as a single decision factor in Tier 3.

There are three main reasons for this approach:

1) Federal Transit Administration (FTA) has required a risk analysis study for “new start” projects since 2002 (TCRP 2009). Therefore the results of risk analysis would be often available to decision makers.

2) Allocation and quantification of risks is a part of PPP-PSC comparison and there is an overlap between the approach used in Tier 3 and PPP-PSC comparison and the results of one study can be partially used in the other one (e.g. risk allocation matrix).
3) Risk allocation is the only important and independent factor that can distinguish between the performances of two PDMs after going through the first two tiers of the proposed decision support system.

The Tier 3 optimal risk-based approach will leverage the current cutting-edge risk-based cost estimating methods that have emerged in the transit and highway agencies in the past few years (Touran et al 1994; Parsons et al 2004). The user should first complete Tier 1 and Tier 2. It is expected that most of the times the delivery method decision can be made by completing these two tiers. Even if a clear choice cannot be established after going through the first two tiers, at least the first two tiers will eliminate one delivery method and short-list the number of viable choices. It is expected that by the time the decision-makers get to Tier 3, they are only looking at two candidates for the delivery method. This is important because the effort involved in using Tier 3 (especially the quantitative approach) is considerably larger than either Tier 1 or Tier 2.

The risk-based approach as proposed here consists of two phases. The first phase is a qualitative approach consisting of developing a risk allocation matrix that clearly portrays owner’s risk under competing delivery methods. By reviewing these risks, the owner (in our case mostly the transit agency) will have an opportunity to decide if a specific delivery method is superior. If this analysis cannot provide a definitive answer to the delivery selection question, then a quantitative approach should be considered. The quantitative approach emphasizes the effect of the PDM on project cost and schedule.

As can be observed in Figure 6.2, a two-phase approach is suggested for the risk-based PDM selection. The process depicted should be repeated for all the short-listed PDMs surviving the Tier 2 process. In the first phase, the PDM is selected mainly based on the
Risk Allocation Matrix. This phase of Tier 3 is called the Qualitative approach. If after this phase still more than one choice remains equally viable, then a complete risk analysis would be required to quantify the effect of PDM on project’s cost and duration and finalize the PDM selection. This second process is called the Quantitative approach.

Figure 6.2. Overview of the Risk-based Qualitative and Quantitative Approaches for PDM Selection

A risk-based cost estimate generates a range of possible project costs rather than a single point estimate as seen in Figure 6.3. This distribution represents the combined effect of various risks that affect project cost and also considers the effect of escalation by expressing costs in Year-of-Expenditure. Using this distribution, the project owner would be able to estimate the probability of finishing the project within a specified budget. Alternatively, the owner can establish sufficient contingency budget to keep the probability of cost overrun or schedule delay below a specified threshold.
Figure 6.3. Distribution of Project Costs (in Year-of-Expenditure $M)

The same modeling method (and much of the same data) that is used to generate the cost and schedule risk analysis can be used to make more informed decisions and allocate risks appropriately, in essence, optimizing the project delivery and contracting decisions.

One of the major findings of the structured interviews (conducted with transit agencies as part of this effort) was the apparent effect of a rigorous risk analysis on project success. It was found that projects that paid more attention to risk analysis fared better in terms of achieving their budget and schedule goals. The following sections describe qualitative and quantitative phases in more details.

**Qualitative Approach**

The overview of the process is shown in Figure 6.4. The risk-based approach is superimposed on the project development life-cycle. The most likely time to decide on the PDM is either at the end of the Conceptual Design or during the Preliminary Engineering phase. If the project goes into the Final Design, the agency will lose the opportunity to effectively use alternative delivery methods and will be limited to the
traditional DBB approach. At the end of the Conceptual Design, the agency usually has not done a detailed risk analysis. If the PDM selection decision cannot be finalized by going through the first two tiers described in previous chapters, the agency would need to conduct a preliminary risk analysis in order to be able to make an informed decision regarding the choice of the PDM.

The result of this preliminary risk analysis is a risk allocation matrix. The risk allocation matrix has become an industry standard for legal teams when authoring alternative contracts for large infrastructure projects. Table 6.1 shows a hypothetical risk allocation as envisaged in this decision support system. Risk factors are major events or conditions that can affect the project in a negative way (the events that can affect the project in a positive way are called opportunities and traditionally are far fewer than risks). Care should be taken to consider only the significant risks because otherwise, identifying and

![The Project Lifecycle, Risk Analysis, and PDM Selection Process](chart)

**Figure 6.4. Overview of the Risk-based Approach for PDM Selection**

*(adopted from TCRP 2009)*

The result of this preliminary risk analysis is a risk allocation matrix.
measuring all project risks would be a major effort. For each of these risk factors (that can be arranged according to their impact (rank) or their chronology) a main responsible party should be identified, given a certain project delivery method. As an example, the party responsible for Design defects in a DBB contract is the owner, whereas in the DB contract, the responsible party is the Constructor. To each risk factor, a rating will be assigned as to the effect of the PDM on the treatment of that risk factor, from the perspective of the owner agency. As an example, in Table 6.1, for the hypothetical project under study, the use of a DBB has a favorable effect for “Permits/approvals” risk from the agency’s point of view. It is decided that the agency is the best party to obtain these permits and that the agency can most effectively do this under a DBB approach. A rating of “+” is assigned for such a case. The same risk factor, under a DB delivery method is unfavorable from the agency’s point of view, because the agency feels that the DB constructor is not the best party to obtain various permits and approvals (such as environmental permits). A rating of “—” is assigned for such a case. As another example, the risk associated with “Design Defects” has a rating of “—” for the agency under the DBB arrangement because in this delivery method the agency is responsible for the accuracy of design. A DB approach on the other hand gains a “+” rating for the agency because it transfers this risk to the constructor. In summary, the ratings always evaluate a risk from the standpoint of the agency.

If the choice of a PDM has no effect on a particular risk factor, then a rating of “0” will be assigned. No attempt is made at this stage to quantify the impact of these risk factors (in terms of $ or project delay). After the matrix is developed and rated, the evaluation team can review the outcome and see if any PDM seems superior in terms of its capacity
in dealing with these risk factors. For example, reviewing the matrix of Table 6.1 may lead one to believe that DB is the better choice for the owner agency because of the number of favorable ratings that it has obtained.

Table 6.1. Example of Risk Allocation Matrix

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>DBB</th>
<th></th>
<th>DBB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBB</td>
<td></td>
<td>DBB</td>
<td></td>
</tr>
<tr>
<td>Responsible</td>
<td>Rating</td>
<td>Responsible</td>
<td>Rating</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permits/Approval</td>
<td>Owner</td>
<td>+</td>
<td>Constructor/Owner</td>
<td>-</td>
</tr>
<tr>
<td>Different Site Conditions</td>
<td>Owner</td>
<td>0</td>
<td>Constructor/Owner</td>
<td>+</td>
</tr>
<tr>
<td>Design Defects</td>
<td>Owner</td>
<td>-</td>
<td>Constructor</td>
<td>+</td>
</tr>
<tr>
<td>QA/QC</td>
<td>Constructor/Owner</td>
<td>0</td>
<td>Constructor</td>
<td>+</td>
</tr>
<tr>
<td>Exchange Rate Risk</td>
<td>Owner</td>
<td>-</td>
<td>Owner</td>
<td>-</td>
</tr>
<tr>
<td>Other risk factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Preparation of the risk allocation matrix and rating the risk factors can be accomplished in a reasonable time. If the outcome points to a clear PDM winner, then the decision is finalized and the results, along with justification will be documented. If after going through the proposed process the choice is still not clear, then the process should be moved to a more detailed quantitative approach. It is emphasized that the rating assigned
to each risk factor is chosen from the owner agency’s point of view (and the potential benefits/loss to the owner as a result of a specific PDM).

**Quantitative Approach**

Risk assessment is the identification and evaluation of risks in terms of their likelihood of occurrence and their probable consequences. Likelihood of occurrence and the associated consequences can be expressed qualitatively or quantitatively. If risks can be quantified, it is easier to comprehend their effects on a project and determine whether resources (time, money, or other resources) can be cost-effectively applied to positively influence risk events (Parsons *et al* 2004).

The quantitative approach should be attempted only if the qualitative approach does not result in a clear choice for the PDM. As shown in Fig. 6.4, the quantitative approach is suggested to be used at the conclusion of the preliminary engineering (PE) phase because the owner is expected to have a probabilistic risk analysis on project cost and schedule. The risk analysis process is a major undertaking that will require hundreds of man-hours over the course of several weeks. The outcome of the risk analysis can also be used as input to the PDM selection decision (Fig. 6.5). The quantitative phase of Tier 3 would then be contingent on the availability of the complete risk analysis. If this risk analysis is not a requirement (for example in projects that do not apply for federal funding), then it is suggested that the PDM selection decision be made without this phase as the cost of this phase could be prohibitive. It should be mentioned that the risk analysis is a time consuming process and the decision making will face a delay if postponed until the time risk analysis is finished. Therefore, it is highly recommended that the decision be made based on the risk allocation matrix. This matrix does not require a comprehensive risk
analysis and can be developed without collection and analysis of quantitative data of the project.

Figure 6.5. Risk Analysis Outcome as an Input to PDM Selection

One outcome of a probabilistic risk analysis is a distribution (range of possible values) for project costs and/or duration (Figure 6.6). Also, a risk register which is basically a list of the most important risk factors ranked according to their impact on budget or schedule should be provided as part of the risk mitigation report.

Figure 6.6. A Cumulative Distribution Function of Project Costs (@Risk)
Usually, the number of these ranked risks is limited. For example, in several risk assessments conducted by the Project Management Oversight consultants on behalf of the FTA, the list of significant risks factors were between 10 to 15 (TCRP 2009). This approach follows the logic of the Pareto’s law which states that, for many events, 80% of the effects come from 20% of the causes. In the context of project risks, relatively few risks are responsible for most of the project cost or schedule overruns. The project cost distribution and the list of ranked risks will serve as inputs to the process of selecting the best PDM. For each ranked risk a distribution of risk costs is usually estimated. The highest ranked risks are those with large expected values and large ranges (an indication of high variability of the risk factor).

The proposed process, called the quantitative approach in this dissertation, will involve estimating the effect of each major risk factor on the agency’s budget, assuming a specific delivery method. The process starts by reviewing all the risk factors and selecting those risk factors where the choice of project delivery will affect their value to the owner. This includes the changes in the risk impact, probability of occurrence, or the party responsible for the consequences if the risk materializes. Only the risk factors that are sensitive to the project delivery method will be selected for further analysis. For each of these risk factors, the range of cost will be estimated under assumed project delivery method. This can best be accomplished by some of the same experts that were involved in the risk analysis. The quantitative approach is a powerful tool for comparing competing PDMs. It focuses on those differences between the PDMs that affect cost and schedule and provides a consistent way of evaluating each PDM based on the major risk factors affecting the project. This will allow the decision maker to document the reasons
for the selection of a specific project delivery method. The drawback of this approach is its dependency on the availability of the expensive risk analysis results and the higher skill level required for pricing out each risk under various PDMs. However, the choice of the PDM is a natural outcome of a risk analysis exercise because one of the most important benefits of any risk analysis is risk allocation/mitigation. A properly selected PDM is an effective risk mitigation instrument that can help keep project costs low and minimize project delays.

Example

To better describe such an approach a small case study for the comparison of DBB and DB is presented. The case is assumed to be an extension of an existing light rail. The total project cost is estimated to be $850,000,000. It is assumed that the risk analysis is done for this project and the decision makers have access to its results. Therefore, the risk factors are identified and their impact and probability of occurrence are modeled. It is also assumed that after applying Tier 1 and 2 the remaining options for this project are DBB and DB. It is assumed that the main risk factors that are affected by the change of PDM from DBB to DB are limited to the items mentioned in the Table 6.2. It is also assumed that the inherent uncertainty of project cost estimates and its consequences in precision and reliability of those estimates are considered in Tier 1 and Tier 2. Here in Tier 3 the changes are under consideration not the base costs. The timing of estimation and owners’ willing to have a precise cost estimate early in the project is not of interest here in Tier 3 (These aspects of uncertainty and risk are dealt with in Tier 1 and Tier 2). The changes in the impacts, likelihood, or responsibility of the following risk factors are based on a hypothetical case and are for illustration purposes. Table 6.2 shows the risk
factors that can potentially change in the likelihood, responsible party, or impact by the
change of PDM from DB to DBB. The asterisks (*) show which one of DBB or DB is
affected by that risk factor. For example, final design has a probability of cost overrun in
DBB for which the owner is responsible. As another example, project cost savings
because of schedule compression is deducted from the expected cost overrun in DB.

The impact of each risk factor is modeled with a triangular distribution multiplied by the
budget items affected by that risk factor. For example, “changes in project scope”, “cost
overrun because of the constructor claims”, and “project cost reduction because of
shortened schedule” are assumed to affect the total project; therefore, their impacts are
modeled with triangular distributions multiplied by $850,000,000 which is the total
project cost.
### Table 6.2. Risk Factors Affected by Change of PDM in the Example

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>DB</th>
<th>DBB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 underground tunnel</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>2 retained cut or fill</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>3 final design</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>4 project administration and management</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>5 commissioning cost overrun because of lack of coordination between system and civil</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>6 cost overrun because of the constructor claims</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>7 project cost reduction because of shortened schedule</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>8 unforeseen utility relocation</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>9 force account labors</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>10 changes in project scope</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>11 vehicle performance issues</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Each of the risk factors is given a probability of occurrence (a Bernoulli distribution was used) and an impact (a triangular distribution was used\(^7\)). The tables and figures below illustrate the distributions used for the probability and impact of each factors in DB and

\(^7\) The triangular distribution is defined as TRIANG(min, most likely, max).
DBB. The impact of each risk factor is in the form of a triangular distribution which is multiplied by the budget item.

There are some risk factors that appear in both PDMs with difference in probability of occurrence and/or impact (e.g. changes in project scope). These risk factors can have strong correlation with each other. For example, the risk of cost increase due to “unforeseen utility relocation” can materialize in DBB as well as DB or in none. Therefore, if the decision makers believe that the probability of this risk is positively correlated (either happening in both scenarios or not happening in any of them), assuming a correlation coefficient close to 1 is recommended. In other words, the correlation between the risk factors should be input to the software if determined to be necessary by the decision makers.

Table 6.3. Probability and Impact of Risk Factors in Design-Build (Example Case)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Probability</th>
<th>Impact (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>underground tunnel</td>
<td>$P(x = 1) = 0.3$</td>
<td>Triang(0.1,0.25,0.35) ×100</td>
</tr>
<tr>
<td>retained cut or fill</td>
<td>$P(x = 1) = 0.3$</td>
<td>Triang(0.1,0.25,0.35) ×75</td>
</tr>
<tr>
<td>final design</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>project administration and management</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>commissioning cost overrun</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>because of lack of coordination between system and civil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>cost overrun because of the constructor claims</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>project cost reduction because of shortened schedule</td>
<td>$P(x = 1) = 0.4$</td>
<td>Triang(0.01,0.03,0.035) ×850</td>
</tr>
<tr>
<td>unforeseen utility relocation</td>
<td>$P(x = 1) = 0.5$</td>
<td>Triang(0.1,0.25,0.35) ×15</td>
</tr>
<tr>
<td>challenges in third party agreement</td>
<td>$P(x = 1) = 0.1$</td>
<td>Triang(0.05,0.1,0.25) ×75</td>
</tr>
<tr>
<td>changes in project scope</td>
<td>$P(x = 1) = 0.4$</td>
<td>Triang(0.01,0.025,0.035) ×850</td>
</tr>
<tr>
<td>service level worse than expected</td>
<td>$P(x = 1) = 0.4$</td>
<td>Triang(0.01,0.025,0.035) ×150</td>
</tr>
</tbody>
</table>
Table 6.4. Probability and Impact of Risk Factors in Design-Bid-Build (Example Case)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Probability</th>
<th>Impact (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>underground tunnel</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>retained cut or fill</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>final design</td>
<td>$P(x = 1) = 0.5$</td>
<td>Triang(0.05,0.25,0.45) ×55</td>
</tr>
<tr>
<td>project administration and management</td>
<td>$P(x = 1) = 0.8$</td>
<td>Triang(0.1,0.4,0.6) ×35</td>
</tr>
<tr>
<td>commissioning cost overrun</td>
<td>$P(x = 1) = 0.2$</td>
<td>Triang(0.3,0.45,0.55) ×20</td>
</tr>
<tr>
<td>cost overrun because of the constructor claims</td>
<td>$P(x = 1) = 0.5$</td>
<td>Triang(0.005,0.008,0.01) ×850</td>
</tr>
<tr>
<td>project cost reduction because of shortened schedule</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>unforeseen utility relocation</td>
<td>$P(x = 1) = 0.1$</td>
<td>Triang(0.05,0.3,0.5) ×15</td>
</tr>
<tr>
<td>challenges in third party agreement</td>
<td>$P(x = 1) = 0.2$</td>
<td>Triang(0.05,0.15,0.25) ×75</td>
</tr>
<tr>
<td>changes in project scope</td>
<td>$P(x = 1) = 0.2$</td>
<td>Triang(0.005,0.01,0.015) ×850</td>
</tr>
<tr>
<td>service level worse than expected</td>
<td>$P(x = 1) = 0.2$</td>
<td>Triang(0.01,0.025,0.035) ×150</td>
</tr>
</tbody>
</table>
A Monte Carlo simulation was conducted to find out the total effect of the changes in the project based on the changes in project risks as the PDM switches from DB to DBB. The result is two probability distribution functions, one for DBB and one for DB. The comparison between these two PDFs show that the DBB option results in more costs – the cost of DBB risks minus Cost of DB risks is positive 70% of the time. The following figures better illustrate the outputs of Monte Carlo simulation. It should be mentioned that cost reduction in DB due to schedule shortening is deducted from the rest of the factors in the simulation of the cost of risks in DB.

Figure 6.7. Total Effects of Risk Factors on Project Costs in DB Option
Figure 6.8. Total Effects of Risk Factors on Project Costs in DBB Option

Figure 6.9. Difference between the Total Effects of Risk Factors on Project Costs in DBB and DB Options (DBB minus DB)
The difference between the allocation and quantification (both probability of occurrence and impact) of the risk factors in DBB and DB resulted in the choice of DB. The effect of various risk factors on the total outcome can be examined using a tornado graph (the coefficient value of tornado diagram is correlation coefficient between each factor and the total sum of factors). The tornado graph is used to display a ranking of the risk factors (input distributions) which impact the difference between the performances (the output). As it is shown in Table 6.5 the most important factors in this example are project administration and management, final design, and cost overrun because of the constructor claims for DBB. In the DB option these factors change and the first three important factors are project cost reduction because of shortened schedule, changes in project scope, and underground tunnel. It correlates with the results of literature review (Chapter 2) in which an advantage of DB for the owner is transferring the risks of design to the design-builder and the other advantage is project schedule shortening in DB. And the challenge of DB for the owner was lack of control over the project design which will result in high costs for the owner if some changes in the project design are required after the project award.
Figure 6.10. Tornado Diagram for the Impact of Risk Factors on the Performances of DBB and DB

Table 6.5. Ranks of Risk Factors Affecting the Performance of DBB and DB

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>DB</th>
<th>DBB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 underground tunnel</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>2 retained cut or fill</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>3 final design</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>4 project administration and management</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>5 commissioning cost overrun</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>6 cost overrun because of the constructor claims</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>7 project cost reduction because of shortened schedule</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>8 unforeseen utility relocation</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>9 challenges in third party agreement</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>10 changes in project scope</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>11 service level worse than expected</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
It should be noted that other risk factors had minimal impacts on the output. Also the first factor (changes in project scope) in both PDMs had a noticeable effect and the value shown in Table 6.5 is the sum of its effects on DB and DBB. The other values in Table 6.5 are the product of impact and probability of each risk factor.

**Conclusion**

Tier 3 may be needed in cases where Tiers 1 and 2 cannot provide a clear best choice for the project delivery method. In such a case, Tier 3 can be used at two levels: qualitative and quantitative. Both approaches are based on a risk allocation exercise that will outlay major project risks to the agency under various delivery methods. In the qualitative approach, the decision-makers will base their final decision on the careful examination of each risk factor and after deliberating over the anticipated effect of each risk factor on project cost and schedule. This critical review can help the agency decide on the most appropriate delivery method. If this process still does not yield a final outcome, the agency can then proceed with the quantitative approach. In this approach, the cost and schedule effect of each risk factor will be estimated with an appropriate range, summed up, and used in comparing the total effect of risks under competing delivery methods. The agency can then select the delivery method that results in the most favorable outcome considering both cost and schedule. To illustrate the applicability and usefulness of this methodology, a small case study was demonstrated at the end of the chapter.
Chapter 7. Decision on PPP

Introduction

Decision on PPP is explicitly discussed in this chapter. PPP delivery method includes project financial aspects and requires further consideration of economic factors compared to conventional methods such as DBB. The way decision on PPP should be incorporated into the proposed decision making is discussed in this chapter. The results of a comprehensive literature review on PPP were partly reflected in Chapter 2. As another outcome of this research effort this chapter introduces a two step decision making process in which the appropriateness of PPP is evaluated once before the project advertisement and then after the receipt of private sector proposals. This process was evaluated by a group of experts and was considered to be a strong tool in comparing PPP with other more conventional methods (Chapter 9). The first step (before advertisement evaluation) includes qualitative factors while the quantitative analysis is postponed until after the receipt of proposals. The concept of Value for Money is introduced in this chapter. The calculations of Public Sector Comparator are also explained. The advantages and disadvantages of the proposed approach to PPP evaluation and its shortcomings are analyzed at the end of the chapter.

Existing Procedures for Evaluating PPP Option

Public-Private Partnership has several advantages for the owners of any kind of infrastructure projects. It mainly reduces the need for the capital investment while transferring many project risks to the private sector. It can enhance the innovation and creativity in project design. PPP has also shown some enhancements in cost and schedule
control (PPP benefits were explicitly discussed in Chapter 2). However, PPP has some disadvantages compared to more conventional delivery methods. These disadvantages include: complexity of contracting and requirement for special skills from public sector, high contracting costs, necessity of a favorable finance market, difficulties of defining a complete set of performance specifications, and drastic decrease in the owner’s power to change the project design after award. Reviewing the historical background also shows that PPP method has never been the dominant method of delivering infrastructure projects in any country. PPP does not count for more than 10-15% of the public investment in construction industry of the countries leading the use of PPP like the UK or Australia (HM Treasury 2003; Grimsey and Lewis 2007). Considering the advantages and disadvantages of PPP the question is whether this method is suitable for every project, and if not what are the factors that an owner should take into account when studying the PPP option for a “new start” project.

Northern Territory Government of Australia (2004) reports that Australian jurisdictions have put a minimum limit on the potential PPP projects. They should at least have a total life cycle cost (payments made by government or users) of 50 million Australian Dollars to be eligible for PPP method application. HM Treasury (2006) states that any project with capital expenditure of less than £20 million ($33 million with the exchange rate of 1.63) is not a suitable option for PPP. This is mainly due to expensive and lengthy procurement phase of PPP delivery method. Saving in project costs and shortening schedule in small projects are not enough to justify these expenditures. Considering the usual dollar values of transit projects, it is clear that the project size would not be an issue of concern and almost all of the transit projects are potentially suitable for PPP.
The UK guide for PFI (HM Treasury 2000) suggests that the government should consider the following items when studying the feasibility of PPP method:

  a) The scale and complexity of the project
  b) The scope for innovation in design and operating procedures
  c) The value of transaction
  d) Discrete nature of the service provided

Zhang (2005b) has studied the critical success factors for PPP projects based on the success or failure of several public-private partnership projects and has come up with five main factors and a number of subfactors for each of them. These factors show that choosing PPP for a project would result in a success when the following are present:

  a) Favorable investment environment
  b) Economic viability
  c) Reliable concessionaire consortium with technical strength
  d) Sound financial package
  e) Appropriate risk allocation via reliable contractual agreement

Another study (Li et al 2005a) on critical success factors for PPP projects has introduced the following list of factors:

  a) Strong private consortium
  b) Appropriate risk allocation and risk sharing
  c) Competitive procurement process
  d) Commitment/responsibility of public/private sectors
  e) Thorough and realistic cost/benefit assessment
f) Project technical feasibility

g) Transparency in the procurement process

h) Shared authority between public and private sectors

i) Social support

j) Multi-benefit objectives in both parties

k) Government involvement by providing guarantees

l) Sound economic policy

m) Stable macro-economic environment

n) Well-organized public agency

o) Favorable legal framework

p) Available financial market

q) Good governance (developing policies and administering projects), and

r) Political support.

In another research, Abdel Aziz (2007b) introduces the following list of success factors for PPP projects:

a) “Availability of PPP institutional/legal framework,

b) Availability of PPP policy and implementation units,

c) Perception of private finance objectives,

d) Perception of risk allocation and contractor’s compensation,

e) Perception of Value for Money,

f) PPP process transparency and disclosure,

g) Standardization of PPP procedures and contracts, and

h) Performance specifications and method specifications.”
Characteristics of successful PFI listed in a publication of HM Treasury (HM Treasury 2003) are:

a) Effective management of risks associated with construction and delivery,
b) The private sector has the expertise and experience to deliver a PPP project,
c) The technology and other aspects of the project are stable and no fast-paced changes are in sight,
d) The structure and nature of the service is appropriate for a performance specification in a way that ensures effective, equitable and accountable delivery of public services into the long term,
e) Risk allocation between public and private sectors can be clearly made and enforced,
f) The dollar value of the project is large enough to ensure that procurement costs are not disproportionate, and
g) Planning horizons are long-term with assets intended to be used over long periods into future.

A National Cooperative Highway Research Program (NCHRP) synthesis (2009) suggests that four major factors should be considered in the evaluation of PPP option: 1) valuation of alternative approaches, 2) appropriate risk transfer, 3) transparency and public participation, and 4) complexity of the transactions. The report recommends the use of Value for Money test as a well-known method for the valuation of alternative approaches but does not give case studies or detailed procedures.

HM Treasury as the leading public entity for implementing private partnership in infrastructure projects has published a guide for the assessment of PFI option in a new
project. Based on Value for Money Assessment Guidance (HM Treasury 2006), the public owner should evaluate the PFI option at three different levels: program level, project level, and procurement level. Following this method, the owner should first make a general assessment of the investment program by checking the presence of some key success factors (e.g. market interest, innovation, operational flexibility, and risk allocation mechanism) for PPP in that sector (Figure 7.1).

Figure 7.1. HM Treasury’s Suggested Process for Value for Money Evaluation

The next step is to develop a PSC for the project, and the final step is PPP market evaluation. Public Sector Comparator (PSC) is a benchmark used to determine whether or
not the private proposals offer better value for money to the public. It includes an
estimate of the project costs if executed with another delivery method rather than PPP. It
also has an element for the risks transferred to the private sector (more details on PSC are
provided in the following parts of this chapter). The guide includes a set of qualitative
and quantitative tests but clearly concentrates on financial aspects and insists on the
importance of value for money criterion. Viability, desirability, and achievability of a PFI
project underpin the whole assessment in this guide. Some of the factors to consider
when evaluating these three aspects of a new project at all the aforementioned three
levels (program, project, and procurement level) are flexibility in project life cycle,
outsourc or in-house O&M services, equity and regulatory issues, improvement in risk
management, scope for innovation, contract duration and the residual value of the project
assets, effective management of resources, financial incentivisation, and market interests.

Transit projects (as discussed in Chapter 2 about their characteristics) are not money
makers regardless of their delivery method; so the very first factor a project should have
to become eligible for a PPP seems to be absent in the analysis. But as some authors have
noted (Faruqi et al 1997) and state of practice shows, if a project is not financially viable
but can achieve political, social, or environmental objectives, then governments may
provide some support to make it viable and attractive for private investors. There are a
number of options available to most governments to make a project more desirable to
private investors such as grants and subsidies, tax reduction, guarantee against inflation
or exchange rate, guarantee the minimum ridership volume, property development rights,
and compensation for any change in laws and regulations (Zhang 2005c). In other words,
a transit project needs some sort of government subsidy throughout its life cycle. The question here would be if PPP option would be less costly.

PPP may be found a poor option for projects in which the transaction costs of pursuing PPP are not proportionate compared to the value of the project; or for those projects in which constant changes in technologies make it difficult to establish reliable long term requirements for the project (HM Treasury 2003). For example a highway or a fixed guideway can be good candidates because the service they provide for commuters is expected to be desirable for a long period of time without any major change.

Different professionals and authors have suggested their own list of critical factors to be considered. The most important issue to consider when reviewing these sets is to check their comprehensiveness; it is of utmost importance to have a set that does not leave any influential factor out. A comprehensive set of critical factors is the most important element of a requisite model. This dissertation has thoroughly reviewed the available decision procedures and has taken into account the overlaps and carefully studied the differences. The result is a set of critical factors and a two step decision procedure which is explained in the following part.

**Proposed Decision Procedure**

Based on the literature review described above and the distinguishing characteristics of transit projects (Chapter 2), a procedure is proposed in this part of the dissertation to be followed for the evaluation of PPP delivery method in a new start project.

This procedure encompasses the qualitative factors as well as the Net Present Value (NPV) calculation in the framework of Public Sector Comparator (PSC) as the
quantitative factor. The qualitative and the quantitative factors are combined in the framework of a weighted matrix (Please refer to Chapter 5 for more information on the procedure). The qualitative factors are not evaluated at the same level. Some of them deal with a larger picture of construction industry while some others become project specific. An important issue to consider is the timing of this evaluation. The owner of a new start project can evaluate the qualitative factors and prepare the PSC relatively early but will not receive the private sector proposals for the project unless the choice of PPP is approved and publicly advertised for the project. Therefore the evaluation of PPP should have two steps: before advertisement, and after receiving the private sector proposals. The PPP method would be literally tested twice; first qualitatively and second with a combination of qualitative and quantitative factors. In the “before advertisement” phase the owner should check a set of factors to make sure in case the PPP method is selected for the project after receiving the bids, it will be successful. In the first step the local applicable laws and regulations related to PPP, presence of a favorable investment environment and competent private sector, social and political factors influencing the success of PPP, and capability of the owner agency in managing a PPP project should be assessed. In case the PPP method passes the first step, PSC should be prepared and then the project be advertised to the public. After the bids are received, a financial comparison between the bids and the PSC should be done as a major influential factor. The result of this comparison along with a number of qualitative factors shapes up the second step of PPP method evaluation.
Before Advertisement

The owner should evaluate the appropriateness of any delivery method before advertising the project to the public. The decision should be based on the advantages and disadvantages of each delivery method and the nature of the project at hand. Some of these factors may cancel out a delivery method or almost negate its advantages with respect to other factors. In these cases, the owner should eliminate that delivery method and consider the implementation of another method from the remaining options (Figure 7.2). The same procedure should be followed for PPP. Nevertheless, procurement phase of PPP method is relatively lengthy and the decision on selecting this method should be made as early as possible in the project life cycle. For that matter, the owner needs to collect information on the PPP advantages/disadvantages and also the general characteristics of the new start project. Having collected the information, the owner needs to consider the following factors in the evaluation of PPP appropriateness.

Figure 7.2. The Value for Money (VfM) Test Flowchart
1) **Project size:** The dollar value of the project is an influential issue in PPP method because of the relatively high expenses of its procurement and transaction phase. Lengthy negotiation and hiring different consultants by the owner to handle various aspects of PPP necessitates the definition of a minimum limit for project costs so that these costs can be justified by the savings in the project. This threshold should be determined by a federal agency and in the absence of such a definition, the state or local agency needs to consider this factor and predetermine a minimum for any project becoming a candidate for PPP method. The governments with more experience using the PPP such as the UK or Australia have both put in place a minimum limit for project costs (around $20 to $40 million). When the cost of building a new fixed guideway exceeds a hundred million dollars these limits are obviously far less than any transit project budget. In other words, as long as the project under study is a new project (BRT, LRT, or HRT) it can be a good candidate for PPP.

2) **Investment environment:** A vital element of any PPP project is the willingness of private sector for investment. This factor is dependent on a number of other factors that shape the investment environment. Some of these factors are the availability and readiness of financial institutions to invest in an infrastructure project, the political support for the PPP method, favorable legal atmosphere, availability of required governmental supports of the project in terms of subsidies and grants. It is clear that the major detracting factor for transit projects in attracting private investment is their negative revenue. As mentioned in Chapter 2 (distinguishing characteristics of transit projects), the revenue from the farebox does not even cover the O&M costs. Transit projects are also relatively expensive and capital intensive. The ridership statistics is also
fairly uncertain and private sectors would not usually accept it. Historically, the owner agencies have overestimated ridership to make their project more attractive for getting federal support (Pickrell 1990; Flyvbjerg 2003). These factors make a transit project less attractive to the private sector investors. The only way to change this environment (as will be shown in the case study) is to guarantee a minimum payment to the PPP contractor during the operation phase. Furthermore, the owner should participate in project’s capital costs as there is no realistic possibility that capital costs can be all covered by the private sector.

3) Project viability: Several aspects of project should be studied carefully to make sure that a long lasting PPP contract will be a viable option. Due to the complexity and duration of PPP contracts, the feasibility study demands more attention and encompasses a wider spectrum of issues. Environmental issues, social impacts of the project, technological changes, economical impacts of the project, and technical complexity of the project are some of the factors that the owner should consider while evaluating the viability of the project. One of the interviewees was specifically pointing to the economical effects of a new fixed guideway project on the properties around its corridor. The increase in the price of real estate which is literally the premium paid by the residents to have early access to a reliable public transportation should be precisely studied; it may be possible to include the increase in value in adjacent properties into the PPP agreement as an incentive for the PPP contractor.

4) Private sector capacity: A drawback for all the alternative delivery methods has been the insufficient competition in the market due to the lack of expertise and experience in the design and construction firms. Adding the financial aspects to the project contract has
made the PPP even less competitive and there are not many companies capable of executing a PPP project. Joint ventures and consortiums have solved the problem to some extent but there is an unequivocal need to study the competency and level of expertise in the private sector for a new PPP project. Technical strength, experience with similar projects, experience with design-build projects, and managerial strength are some of the parameters to be checked in evaluating the private sector.

5) Risk allocation: An important advantage of PPP is its ability to transfer some project risks to the private sector (FHWA 2009). The definition and allocation of risks should be carefully studied and a reasonable transfer of risks to the private sector without imposing a huge cost on the owner should be guaranteed. Risk allocation in PPP projects is more complex compared to other delivery methods because of its wide scope, duration, and financial involvement of private sector. The services provided by the project should be discrete enough from the owner that a clear risk allocation matrix can be developed because the private sector should only be exposed to financial penalties resulting from his own performance. In other words, the project risks should not be mixed with owner’s risks.

6) Competency of public agency: Competencies required for managing a PPP project has some similarities with those required for a DB project. A recent research (TCRP 2009) shows that owners tend to put their most experienced staff on DB projects because they need to be better prepared to understand conceptual designs, conceptual estimates, and performance criteria. Managing a PPP project demands a set of new skills in the owner’s organization. Financial complexity, service-based projects, duration of the project, bundling the design, construction, operation, and maintenance of the project, risk
management, and lengthy and complicated negotiations during the procurement phase are some of the skills that are required for a successful management of a PPP project. The availability of such skills (either in-house or by hiring few consultants) should be studied before hands (FHWA 2009).

7) **Potentials for improving Value for Money (VfM):** A major factor in selecting PPP is its ability to improve VfM. Value for Money is “the optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user’s requirements” (HM Treasury 2006). PPP can increase the VfM by shortening the schedule, reducing the project life cycle costs, and implementing innovative solutions. Bundling the design, construction, O&M, and finance of the project allows the private sector to come up with designs and solutions that can increase the value for the money spent on the PPP projects. Although the amount of savings is not known until the private proposals are received later, the owner can still study the potential for some improvements in VfM mainly by comparing the new start project with similar previous experiences, potential for innovation in the design, and possibility of schedule shortening.

8) **Development of performance specifications:** The PPP project will be awarded to an entity which is usually a joint venture of a designer, a contractor, and an investor. This entity is responsible to design the project and then build it in a way that it can fulfill the expectations of the owner in the operation phase. The owner should be able to define these expectations clearly in the performance specifications early in the project. This is fundamentally different from traditional specifications that are prepared when the design is 100% complete. Performance specifications should be prepared at the time when the design maybe only 30% complete. Because these specifications are the main documents
submitted to the contractor, possibility of developing them for a new start project in a way that they can guarantee the future performance of the facility is vitally important. Another research (TCRP 2009) shows the importance of performance specifications in DB projects (where the design is not complete) and gives examples of the projects that have had adversarial relationships due to the different interpretation of project performance specifications.

After Receiving Bids

If the choice of PPP method for a project passes the first phase of evaluation and becomes a plausible option, the owner should consider the project advertisement in order to receive proposals from those in private sector who are willing to become partners in the project (Figure 7.2). The owner may still refuse to advertise the project with a PPP method for several different reasons. That is why some governments like the UK have mandated a minimum percentage of projects to go PPP. One major drawback that makes some owners prefer more traditional methods over PPP is the loss of control over the project which even extends to its operation phase.

Value for Money (VfM) Test

Public agencies have a set of rules and regulations governing their procurement process. The procedures they should follow and the factors they should consider are developed so that a fair competition is practiced by which the public always benefits from development of new projects with the optimum (and not necessarily the lowest) cost. In this environment, the public entities have a primary responsibility to ensure that Value for Money (VfM) is achieved in all kinds of procurement. Value for Money is defined by
HM Treasury (2006) as “The optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user’s requirements.”

Value for money, a well-known technique to evaluate PPP (NCHRP 2009), is a relative concept and is analyzed and understood with respect to a comparison of the potential outcomes of alternative options. In other words, VfM analysis in PPP is based on a comparison between the conventional method and the PPP. The VfM calculation consists of a series of cost and time estimates, prediction of several financial factors (e.g. escalation rate, interest rate, etc.), and risk identification and quantification. In the financial calculations, simply benchmarking the current situation and extrapolation of available data may mislead the decision makers. Due to the potential changes in the market, level of demand and technology, the level of uncertainty in the predictions and estimations is high which needs to be addressed or at least considered in the analyses.

Public Sector Comparator (PSC)

The Public Sector Comparator (PSC) is a benchmark used to determine whether or not the private proposals offer better value for money to the public. “The PSC is based on estimates of full costs, revenues and risks, set out in cash flow terms, discounted at a public sector rate to an NPV. It is compared with the discounted value of payments under the PSC along with the adjustments for risk and costs retained.” (Grimsey and Lewis, 2005a). The concept was first developed in England. Australians and mainly Victoria State Government have modified the British model (Quiggin 2004) and others like Canadians are also using this concept. PSC is indeed based on a reference project which reflects the raw comparator. Then the result of risk allocation to the parties is added to the raw costs and the PSC is calculated. The PSC only includes the financial costs and
benefits of the project. It does not cover all the benefits of the project that are normally considered in a cost-benefit analysis at a feasibility study. In other words, PSC calculations are assumed to be preceded by project feasibility study. The PSC should be developed in sufficient detail to ensure that an adequate benchmark in terms of quality, design and cost is provided with which the bid proposals can be compared. The level of detail depends on project scope, size of investment, project risks, maturity of PPP sector, and past experience with PPP projects; as each project is unique in nature, there is no guide that can be universally applied to every project. PSC has the following advantages:

- It promotes life cycle cost analysis early in the project,
- It is a key measurement benchmark during the procurement process and helps the project owner to focus on the output specifications, risk allocations, and comprehensive costing,
- It is a means of testing VfM,
- “It encourages competition by generating confidence in the market that financial rigor and probity principles are being applied” (Grimsey and Lewis 2005a).

PSC should be calculated before any bid is received because it should not be influenced by the bids and should remain the ‘pure’ opinion of the project owner.

There are some embedded assumptions in calculating the PSC (Grimsey and Lewis 2005a):

- The financial source required at the beginning of the project for the owner to be able to start the project is assumed to be available. If the public sector by no
means can afford to do the project due to the shortage of financial sources or budget deficit, the PSC test becomes much less important.

- The procurement time needed to pursue the public convenient method after rejecting the PPP is neglected. In other words, any shift in the start date and finish date of the project is neglected.

- Only the costs associated with implementing the reference project should be included in the PSC. The costs of running the overall PPP process should be obviously considered but should be excluded from PSC calculations.

- Output specifications and standards considered in PSC calculation should be equal to the ones expected from PPP contractors and previous performance of public or private sector should not influence the equality of the level of standards.

Most of the documents found in the literature (like Partnerships Victoria, 2003; Grimsey and Lewis 2005a; NCHRP 2009) divide PSC into four major elements:

**1) Raw PSC:** Raw PSC (baseline costs) provides a base life cycle costing (capital costs as well as operation and maintenance costs) of a reference project. Defining the reference project is the core element of PSC calculation. The reference project is “the most likely and efficient form of public sector service delivery that could be employed to satisfy all elements of the output specification, as outlined in the project brief, based on current best practice” (Victoria State Government 2003). In the calculations of a reference project, it is assumed that the public sector contracts out any part of the project for which there is not enough in-house capabilities. Raw PSC is a full and fair estimate of the reference project costs if delivered publicly. It means that the raw PSC includes all the costs (cash
outflows) of the project executed through the most likely public procurement method. The PSC is based on the cash flows and does not include depreciation or similar items. Instead it considers the value of fixed assets if they are purchased for the project or even if they are pre-existing assets that would be used in this specific project. It is based on the historic data available on the similar projects with some modifications related to the specific goals, objectives and conditions of the new project (e.g. new technology, size, regulations, changes in demographics and location). It includes:

- Preliminary design, costs of obtaining approvals and permits,
- Design and construction costs including demolition, material, equipment, land, and inspection,
- Opportunity costs of using existing assets,
- Operation and maintenance costs like staff wages, consumables, utilities, audits, and quality assurance,
- Management and facility overhead like accounting, IT, and project management,
- Any decommissioning costs at the end of the project (if applied).

All the costs mentioned above should be raw costs and no contingency should be added to them. Project risk analysis should decide on the amount and distribution of contingency budget. Also, the data used to estimate the raw PSC should be obtained from a “normal year” so that it reflects the most likely outcome in a typical year (a normal year is different from an average year as the latter is based on a mathematical average of outcomes). (Industry Canada 2002).

2) Transferable risks: A key motive for public owners to select PPP is transferring risks to the private contractor. The monetary value of risks transferred to the PPP contractor
should be calculated and added to the NPV of PSC. In order to do so, a comprehensive risk register with the probability and impacts associated with each registered risk is required. Historical data of similar projects can help the owner develop such a risk register. “Australia reports that the average value of transferred risks on PPP projects across Australia appears to be around 8 percent. Transferred risks as a percentage for total PSC in the UK is within the range of 10-15 percent.” (Grimsey and Lewis 2005a). Table 7.1 is an example of risk sharing between the private sector and the public sector in DBB and PPP. Figure 7.3 also illustrates the concept of PSC-PPP comparison. The comparison between these two PDMs shows the areas for which some risks are transferable to the private sector.

3) Retained risks: Not all the project risks are transferable to the PPP contractor. The monetary value of these retained risks should be calculated with the same methodology used for transferable risks and then added to the PSC. However, this portion is not playing a role in PPP-PSC comparison simply because it is equal in both scenarios.

Table 7.1. Risk Sharing in PPP and DBB

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>DBB</th>
<th>PPP</th>
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<tbody>
<tr>
<td></td>
<td>Public Sector</td>
<td>Private Sector</td>
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<tr>
<td>Design</td>
<td>X</td>
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Adopted from a PricewaterhouseCoopers presentation (2008)
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<tr>
<td>Errors and Omissions</td>
<td>X</td>
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<tr>
<td>Coordination</td>
<td>X</td>
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<tr>
<td>Lifecycle</td>
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<td>Construction</td>
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<td>Performance</td>
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<td>X</td>
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<tr>
<td>Schedule*</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Cost Overrun*</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Changes in Scope</td>
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<td>X</td>
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<tr>
<td>Force majeure</td>
<td>X</td>
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<tr>
<td>Financing</td>
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<td>Additional financing</td>
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<tr>
<td>costs due to schedule slippage</td>
<td>X</td>
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<td>Interest rate volatility*</td>
<td>X</td>
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<td>O&amp;M</td>
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<td>Supply/performance of vehicles</td>
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<td>Defective components</td>
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<td>Maintenance level</td>
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<tr>
<td>Service level and quality</td>
<td>X</td>
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4) Competitive neutrality: “Competitive neutrality adjustments remove any net competitive advantages that accrue to a government business by virtue of its public ownership.” (Grimsey and Lewis 2005a). Australians (Victoria State Government 2000) define the objective of competitive neutrality as “the elimination of resource allocation distortions arising out of the public ownership of entities engaged in significant business activities. Government business should not enjoy any net competitive advantage simply as a result of their public sector ownership.” If the public entity decides to award the project under a PPP structure, a portion of the PPP costs related to the contractor’s tax payments will return back to the government. On the other hand, any purchase in the framework of alternative delivery method is subject to tax.

Calculating the difference between the amounts of tax returned to government under PPP and the alternative method is very difficult if possible (Grimsey and Lewis 2005a). Instead, it is advised to identify the additional tax flow that arises because of the PPP structure and add that as the competitive neutrality to other costs in PSC calculation (Partnerships Victoria 2003). These taxes may be related to local government, land tax, and similar taxes that do not apply to the government itself. It should be noted that this

<table>
<thead>
<tr>
<th>Revenue</th>
<th>X</th>
<th>Availability Model</th>
<th>Revenue Model</th>
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*The risk allocation in these items depends on the wording of the contract and should not be generalized to all kinds of DBB or PPP.
part of PSC is usually less than 5% of the raw PSC and does not usually play a decisive role in PPP-PSC comparison (Partnership Victoria 2003).

Figure 7.3. PSC-PPP Comparison

(adopted from Grimsey and Lewis 2005a)

The PSC is calculated at the early stages of project and is not based on a detailed design of the project so it can be always argued that PSC calculations are too subjective and can be easily manipulated. It is undoubtedly true to claim that PSC is not accurate enough specially by adding the monetary value of transferred risks to the base costs of PSC. In order to partly fix this shortcoming, the decision on PPP should not be solely based on a PSC-PPP comparison. There should be other qualitative factors included in the decision process. Another approach to improve the quality of PSC estimates is to impose a pressure on the public entity to use the same PSC estimates when applying for governmental funds. In this case, the public entity will be held accountable for the
estimates. Also, while the PSC is based on an early stage estimate of project costs and risks, a PPP bid is a proposal developed by a contractor who is ready to commit himself to his offer and do the project. As a consequence, the level of risks associated with the NPVs derived from a PSC calculation is different from that of a PPP bid proposal, which means that there is a higher possibility of facing a cost overrun beyond the estimates of PSC (Grimsey and Lewis 2005a). The main solution for this shortcoming is to conduct a sensitivity analysis of PSC estimate. Conducting a sensitivity analysis on the results of PSC is suggested to get a better picture of the project’s financial status. The sensitivity analysis should focus on those influential parameters that may vary over time and they include interest rate, construction costs, and operation and maintenance costs.

Qualitative and Quantitative Analysis of PPP

The evaluation of PPP option should be both qualitative and quantitative. The VfM which is essentially an evaluation process is divided accordingly; the quantitative part results into the PSC, and the qualitative part would be the consideration of a set of crucial factors that can approve or veto the project. The level of detail of the evaluation depends on the importance, size and complexity of the project, and the time in the project life cycle when the decision is made. HM Treasury (2006) categorizes the qualitative factors into three major elements: viability, desirability, and achievability. It also requires the evaluation of the project effects on the public sector employees. Adding some other factors like the contract length, market analysis, etc. is dependent upon the availability of information and the project importance to the owner. Victoria State Government (2003) considers service delivery, design amenity, sustainability, and unquantifiable risk transfer as qualitative factors that are applicable to most projects.
The quantitative part, which is the net present value of PSC, consists of two major parts:
1) the expected life cycle costs of the reference project if done by the public sector, and
2) the quantified risks allocated to the private sector. The project costs over its life cycle consist of both the direct costs and the indirect costs. So the PSC includes all the initial capital outlay, operation and maintenance costs, major upgrades, transaction costs, administrative costs, third party revenue, etc. After the estimation of project life cycle costs are complete and expressed in NPV, an amount should be added to this raw estimate which is equivalent to the value of the risks transferred to the private sector. The project risks can be broadly divided into transferable risks and retained risks. The burden is on the public sector to identify, classify, and quantify the transferable project risks. The risk analysis aspect of PPP is so important that can simply invalidate a project (Please refer to Chapter 6 - Risk-based Approach and Chapter 8 - Hypothetical Case Study for more discussion on risk analysis).

The combination of a set of quantitative and qualitative factors can be best done in a weighted matrix framework. The procedures of weighted matrix and some examples were provided in Chapter 5 (Multi-Criteria Decision Approach). The decision makers can apply the same procedure here to analyze the relative importance of qualitative factors and the PSC as the only quantitative factor. It should be noted that the significance of a favorable PSC is much more than the qualitative factors and one would assume that this would be the single factor to consider but due to the uncertainty involved in estimates and assumptions in PSC calculation it is highly recommended that the decision makers consider the qualitative factors beside the PSC calculations.
The Problems with VfM and PSC

Despite its strengths and advantages to the owners, PSC calculation has faced criticism. The followings are a number of more important issues found in the literature (Grimsey and Lewis 2005a):

1) The comparison between the PSC and PPP comes down to the difference between two very large numbers expressed in net present values. This difference is often small and is certainly very sensitive to the assumptions made for risk allocation and PSC calculation.

2) The difference between the PSC and PPP is too sensitive to the discount rate chosen for the NPV calculation.

3) As the PPP contracts usually last for decades, overemphasizing the role of PSC-PPP comparison in decision making is flawed.

In order to overcome the first two problems associated with the nature of PSC-PPP comparison, a sensitivity analysis can be conducted to check the robustness of the results. Faruqi et al (1997) did a sensitivity analysis on the feasibility of a PPP project to analyze the effect of changes in major parameters like discount rate.

The third concern will best be addressed if a combination of qualitative factors is considered along with the PSC-PPP comparison. As mentioned before a weighted matrix approach suits the best for this problem.

An important topic in PSC calculation is the choice of discount rate. There are several methods and approaches for forecasting the best and most realistic discount rate, each with its own strengths and weaknesses. Comparison of these approaches and evaluating
each of them is beyond the scope of this dissertation, however due to the important role of discount rate in PSC-PPP comparison, a comprehensive study was done on this issue and the results are discussed in the following part of this dissertation.

The PSC and in general VfM calculation should address some of the concerns that usually hinder the use of PPP. Issues like violation of environmental codes, public employees’ lay-off, deterioration of public service for the sake of project feasibility, conflicts between public and private sector interests, participation of small or medium size enterprises, and fair competition are some of the potential barriers for PPP. Most of these issues should be taken into account in the qualitative analysis part of the VfM.

The PSC helps the owner determine if the project is a viable option in terms of VfM analysis and also helps him check if the received bids are reasonable and affordable. Absence of such a benchmark may cause a dilemma especially when the project is large and complex. It is recommended that in the absence of the PSC calculations, a benchmark should be established by analogy or another plausible technique to ensure that the bids are in the rough order of magnitude range (Industry Canada 2002).

Although the presence of a complete PSC calculation is of great help for the owners of new projects, it can be misleading if not developed with precision and accuracy. There are some pitfalls in the calculation process of PSC that are worth mentioning here (Victoria State Government 2003):

- Use of inappropriate financial model
- Use of weak and untested assumptions in predicting the future of the project
- Inappropriate risk identification and risk quantification

- Underestimation of the effects of external factors on demand and project schedule

- Failure to record assumptions, sources of information, or validation process of the PSC

- Biased estimation of project costs in order to promote it (underestimation) or to kill the project (overestimation)

**Discount Rate**

The cost of capital for a governmental agency is the opportunity cost of funds (money) provided to that agency. The recipient agency should provide a return that covers the cost of opportunities. The rate at which the money is lent to a governmental agency is not necessarily the same as the rate of return a private sector is expected to pay back when borrowing money. The government can borrow money for lower rates while the private companies should pay higher interest rates for the financial sources they use in developing a project. The cost of capital is the sum of risk-free rate of interest, inflation rate, and the risk premium adjustment assigned to any project (Touran et al. 1994). The risk-free rate of interest represents the investor’s desired growth in purchasing power. The rate of return on Treasury Bills could be used as the risk-free rate of interest (Touran et al. 1994; FTA 1998). Inflation also affects the purchasing power of money with a higher volatility compared to risk-free rate of interest. The owner has some level of control over the risk premium portion of the cost of capital and the other two elements are determined by the financial market. Grimsey and Lewis (2005a) combine the inflation and the risk-free interest rate into one element and refer to it as the ‘Social Time
Preference Rate’ (STPR) which is a rate the society is willing to pay for receiving something (goods or services) now rather than in the future.

The interest rate (discount rate) used in an NPV calculation is not any different and consists of the same elements. It should be emphasized that there are two separate rates of return (interest rate) used in a PPP project. One is used by the private sector in its own financial analysis. The other rate is used by the owner in NPV calculation and PPP-PSC comparison. The rate of return used by a private entity in the financial calculation of its own proposal is beyond the scope of this dissertation. It can be any rate chosen by that private entity based on its desire to get the project, investor’s expected rate of return, project and owner’s risks, etc. The rate used in PPP-PSC calculation is the rate used by the project owner and should not necessarily reflect the private sector’s desired return on investment.

There can be two main approaches in selecting and calculating the PPP-PSC interest rate for NPV calculation of future cash flows. One way is to take into account the risks and uncertainties in the cash flow and use a risk-free interest rate and the other one is to use a risk modified interest rate and a cash flow without any risk embedded into it. This dissertation is using the second approach and the interest rate used in NPV calculation is a risk modified interest rate. This approach does not need a risk adjusted cash flow; plus, the suggested risk modified interest rate by FTA (Office of Management and Budget 2003) can be used.

Escalation should be taken into account in constructing the PSC. Generally this should be done by applying the current long-term inflation forecast. However, if there is a reason to
believe that some items may increase in price faster or slower than others, it may be worth using different escalation assumptions for different items. For example, if wages may increase faster than escalation and the project has a large labor component a different escalation rate should be applied to wages. For consistency, if the PSC includes escalation, bids from the private sector should include the effects of escalation too. The project brief should inform bidders of government’s inflation general assumptions to promote a level of consistency in assumptions between the PSC and bids received.

Agencies have different levels of risk acceptance, countries have different investment risks, projects have different levels of complexity and uncertainty, and decision makers have different interpretations of a desired return on investment. Accordingly, there is no consistency in the literature about the most appropriate interest rate to be used in the calculation of PSC and NPV of the bids received from the private sector. In the UK, HM Treasury (2003) suggests that the discount rate to be used in assessing the present value of any investment proposal should be the sum of two components. The first component is about 3.5-4 percent which is solely based on social time preference. The second component is the allowance for other factors mainly related to the project risks, such as the taxpayers’ exposure to extra costs due to the possibility of project cost overrun. The interest rate (the sum of STPR and risk premium) used in NPV calculation in the UK has been around 6% (Grimsey and Lewis 2005a). Industry Canada (2002) states that the interest rate to be used should reflect the public sector value of money plus a possible premium for the systematic risk inherent in the project. It suggests that the public sector should use the private sector’s cost of capital which takes the risk into account because using the public sector’s internal cost of borrowing inevitably reflects an implicit tax
subsidy. Grimsey and Lewis (2005a) report that some public authorities use their long-term borrowing rate as the interest rate simply because that is the interest rate they pay for the money borrowed to fund the expenditures. Partnerships Victoria (2003) suggests that the interest rate should be determined by the risk band that the project falls into. For example if the risk is considered to be very low, then the real time interest rate of 5% should be chosen; for a low risk project, 6%, and for a medium risk project, 8% is recommended. It also states that for most projects, the same interest rate should be used by government in comparing PSC and bid cash flows. UK and Australian public sectors have used a 6.0 percent real time interest rate in PSC calculations while UK has adopted an STPR of 3.5 percent (a risk component should be added to STPR to calculate the real time interest rate). In Australia (namely, State of Victoria) a new guide (2003) on interest rate recommends a unique approach for calculating the interest rate in each project on the grounds that every project has specific characteristics and consequently a unique set of risk factors that affect the interest rate. State of Victoria (2000) uses an 8% rate of return for the purpose of competitive neutrality pricing.

Another problem in PPP-PSC comparison is whether or not the interest rate for the NPV calculation of Public Sector Comparator and the NPV of PPP proposal should be similar. One can refer to the fact that the public fund is coming from taxes on private sector by which they could invest in other projects, and so the interest rate to be used should be similar to that of the private sector. For example Northern Territory Government of Australia (2004) disregards the government’s credit strength and recommends using a similar interest rate which mainly reflects the project risks. State of Victoria (Australia) does the same thing. The UK does not distinguish between these two rates either.
However, there are few criticisms to that approach. For example, Grout (1997) proposes a lower interest rate for public sector. He claims that the interest rates used in the calculation of PSC and PPP should be different. He states that “failure to do so will suggest that private provision is less efficient than public since the present value of private provision will be overestimated relative to public.” Others argue that the lower interest rate for governmental entities is flawed because the risks are not assessed properly (Grimsey and Lewis 2007). In other words, if the transferred and retained risks are valued correctly, the interest rates would be closer if not the same because as mentioned above, the owner entity uses the interest rate in the PPP-PSC comparison and this rate is selected for the public fund which are coming from taxes on private sector. This dissertation suggests the use of equal interest rate in the NPV calculation of PPP and PSC because:

1) The risks in PPP and PSC are not identified in detail due to the early decision making in the project life cycle. Accordingly, one cannot precisely account for the difference between the interest rates with the difference in the level of project risks in case of PPP and PSC.

2) A lower discount rate in PSC will increase the NPV of costs; therefore PSC will become a worse option compared to PPP \( (NPV = \sum_{k=1}^{n} \frac{c_k}{(1+i)^k}) \). However, this research has not found a state or government that applies two different interest rates and there is no guide for determining two different interest rates by the PSC and the PPP proposal. As a result, there is no data or study that supports the advantage of using two different interest rates.
The interest rate used in PPP-PSC comparison is not the same as the one used by the private companies in their own calculations, nevertheless there is a correlation between these two rates. So a study of rate of returns in PPP or PFI projects gives an indication for the appropriate rate that should be used by the owners in PPP-PSC comparison. The projected rate of return of a project should be proportional to the amount of risk the private sector is bearing. PricewatcherhouseCoopers (2002) studied the projected rates of return of 64 PFI projects to ascertain whether the returns that the private sector expected to earn for managing and bearing risk were excessive or in line with what might be anticipated from a competitive market among bidders. This study assumes that project internal rates of return should reflect exactly the returns required by diversified investors as indicated by the weighted average cost of capital (WACC). The average internal rate of return (IRR) of this sample was found to be 7.7 percent per annum. (Grimsey and Lewis 2007).

Precise forecasting and quantifying of the financial impacts of changes in the interest rate on the project is extremely difficult if not impossible. For that matter, Grimsey and Lewis (2002) suggest the use of sensitivity analysis to examine the impact of changes in interest rate and also inflation rate on the feasibility of a project to be delivered with PPP method. A similar approach is used by Faruqi and Smith (1997) to analyze the sensitivity of an LRT project in Pakistan to the changes in government subsidies and delays in project completion. Also, the TCRP report (2002) on financing capital investments does not suggest any specific interest rate but it recommends the use of sensitivity analysis to check the effects of change in the interest rate on the feasibility of a project.
The interest rate used in the PPP-PSC calculations of the proposed method of this dissertation is 7% because:

1) This rate is what the federal government uses when assessing projects for federal funding (Office of Management and Budget 2003).

2) As mentioned in this part of the dissertation, the rate of returns used by other states and governments also falls in a range of 6% to 8%.

3) A sensitivity analysis will be done to examine the effect of changes in the interest rate on the outcome of PPP-PSC comparison.

Conclusion

Inclusion of public-private partnership in a PDM selection system along with conventional methods of DBB, DB, and CMR is a major step forward to reach a comprehensive decision support system that covers all the available options to the owners. This chapter explicitly discussed the comparison between PPP and other PDMs. PPP delivery method includes project financial aspects and requires further consideration of economic factors compared to conventional methods such as DBB. This chapter introduced a two step decision making process in which the appropriateness of PPP was evaluated once before the project advertisement and then again after the receipt of private sector proposals. A set of qualitative factors were introduced and then the calculation of public sector comparator was shown. The way decision on PPP should be made was discussed in this chapter. The concept of Value for Money, discount rate and other similar financial factors were taken into consideration in the calculations of public sector comparator. At the end of the chapter a discussion on the advantages and disadvantages of this approach to PPP evaluation was provided. The next chapter illustrates the
application of proposed method. A hypothetical case study is developed at the beginning of the chapter and then the PSC-PPP comparison will be done to show the details of the proposed method.
Chapter 8. Hypothetical Case Study

Introduction

The proposed decision support system was introduced in Chapter 3 and 3 tiers of selecting a PDM from conventional methods were introduced in Chapters 4, 5, and 6 with several examples to show the details. The decision process on PPP was elaborated in Chapter 7. In order to better illustrate that section of proposed decision support system discussed in the previous chapter, a hypothetical case is developed in this part of the dissertation. The decision support system has two major parts: 1) PPP evaluation including preliminary evaluation of PPP, PSC calculation, and PPP final evaluation, and 2) Conventional PDM selection. Here the focus is on the PSC calculation and in general PPP evaluation, except for the qualitative factors because they are straight-forward and do not need an example or further discussion.

The hypothetical project is a “new start” light rail project that connects two densely populated centers and goes through various neighborhoods. It is 11 miles long and has 5 stations. It goes through communities and has both on-surface and underground tracks. It is assumed that based on the three-tier approach for conventional PDM selection, the best delivery method for this project is found to be DBB (among DB, DBB, and CMR). So the Public Sector Comparator (PSC) would be calculated based on this delivery method. Transferable risks and their quantification are also discussed in this case study.
**Project Description**

General Assumptions:

The project design will last 3 years.

The bidding process will last 6 months.

The project construction will take 4.5 years.

The operation period is assumed to be 30 years.

The operating cash flows are all paid at the end of each period.

The cost of capital used by the federal government in discounting the future cash flows is 7%. The same rate is used in the NPV calculations of PSC and PPP.

No contingency is added or embedded in the construction costs.

It is assumed that choosing PPP will cut the design and construction time by two years. It is based on the trends found in the literature and average percentage of schedule shortening as the result of design and construction overlap and creativity of the PPP contractor who will directly benefit from early start of operation phase.
Project Capital Costs

Capital costs for this project are estimated as depicted in Table 8.1. These costs are divided according to FTA’s Standard Cost Categories (SCC) and are all in Year of Expenditure (YOE). The total cost of the project is $1,586,600,000.

Table 8.1. Project Construction and Professional Services Costs in YOE Dollars

<table>
<thead>
<tr>
<th>No.</th>
<th>Major Tasks</th>
<th>budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC 10</td>
<td>GUIDEWAY &amp; TRACK ELEMENTS</td>
<td>362,700,000</td>
</tr>
<tr>
<td>SCC 20</td>
<td>STATIONS, STOPS, TERMINALS, INTERMODAL</td>
<td>268,700,000</td>
</tr>
<tr>
<td>SCC 30</td>
<td>SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS</td>
<td>57,200,000</td>
</tr>
<tr>
<td>SCC 40</td>
<td>SITWORK &amp; SPECIAL CONDITIONS</td>
<td>51,000,000</td>
</tr>
<tr>
<td>SCC 50</td>
<td>SYSTEMS</td>
<td>88,700,000</td>
</tr>
<tr>
<td>SCC 60</td>
<td>ROW, LAND, EXISTING IMPROVEMENTS</td>
<td>172,700,000</td>
</tr>
<tr>
<td>SCC 70</td>
<td>VEHICLES</td>
<td>189,500,000</td>
</tr>
<tr>
<td>SCC 80</td>
<td>PROFESSIONAL SERVICES</td>
<td>396,100,000</td>
</tr>
</tbody>
</table>

Project operation and maintenance costs

The project O&M costs were estimated by the transit agency and based on the financial analysis submitted to FTA, the O&M costs for the first year of operation (nine years from now) would be $79.33 millions (Distinguishing characteristics of transit projects in
Chapter 2 discuss the ratio of O&M costs to the project capital costs) and will increase with a constant rate of 2.6% (as a long term inflation rate). So the O&M costs after a decade will be $102.544 millions and at the end of its 30th year of operation it will be $166.99 millions.

**Project Schedule**

Project preliminary and final design will take 3 years. The bidding and contracting process will take 6 months. Project construction will take 4.5 years. If the project starts now, the commissioning date will happen after 8 years assuming no delays. The details of the project schedule are illustrated in Figure 8.1.

The O&M phase is assumed to be for 30 years from the day of commissioning.

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Dur.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PROJECT DESIGN</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>BID &amp; CONTRACT</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>STATIONWAY &amp; TRACK ELEMENTS</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>STATIONS, STOPS, TERMINALS, INTERMODAL</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>SUPPORT FACILITIES, YARDS, SHOPS, ADMIN. BUILDINGS</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>SYSTEM WORK &amp; SPECIAL CONDITIONS</td>
<td>4.5</td>
</tr>
<tr>
<td>7</td>
<td>SYSTEMS</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>ROCK, LAND, EXISTING IMPROVEMENTS</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>VEHICLES</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>PROFESSIONAL SERVICES</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>OPERATION &amp; MAINTENANCE</td>
<td>30</td>
</tr>
</tbody>
</table>

**Figure 8.1. Project Schedule**
Implementation of Proposed Decision Tool

Raw PSC results (non risk adjusted)

Table 8.1 showed the project costs divided into eight Standard Cost Categories (SCC) following the cost breakdown standards of FTA (Please refer to Chapter 2). These costs exclude any adjustment for escalation. Also, they do not include any contingency. All of them are expressed in the year of expenditure dollars. The total capital cost (in the YOE) of the project based on the provided estimate of its major elements is $1,586,600,000.

Cost of Capital

The interest rate used in the NPV calculations is 7% as the federal government uses the same rate when assessing projects for federal funding (Office of Management and Budget 2003). It will be shown in the sensitivity analysis (Table 8.7 and Figure 8.5) that the comparison between PPP and PSC is very sensitive to the discount rate and a 6% increase in the discount rate (7.5%) will change the decision from DBB to PPP. It should be mentioned that this level of sensitivity is case-based and not all the PPP and PSC options are this much close to each other.

NPV of Raw PSC

The Net Present Value of the project costs are calculated based on the estimates and the discount rate mentioned above. The O&M costs are also included in the project costs. The NPV is calculated to be $1,836,008,804.
Competitive Neutrality

Competitive neutrality is calculated in some cases where there is clear advantage accrued to the government. Difference in tax payments has been the major element of competitive neutrality. For example land tax or local government rates may be applied to some cases. The main purpose of this section of PSC is to identify the additional tax flows that arise because of the PPP structure. In the case of a transit agency this is negligible because the right-of-way is not usually a part of contract, payroll taxes are similar and the transit agencies usually do not distinguish between PPP and PSC when it comes to operation phase. At the same time there is always a possibility to have different local fees or taxes that should be considered in this part if they are significant.

Risk Analysis

During risk assessment exercise, six major risk factors were identified in this project with profound impact on cost that can be transferred to the PPP contractor. They are listed below with the budget item that they affect.
Table 8.2. Transferable Risk Factors Affecting the Project Cost

<table>
<thead>
<tr>
<th>No.</th>
<th>Risk Factor</th>
<th>Budget Item</th>
<th>Major Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unforeseen cut or fill due to different site conditions (DSC)</td>
<td>Retain Cut or Fill</td>
<td>GUIDEWAY &amp; TRACK ELEMENTS</td>
</tr>
<tr>
<td>2</td>
<td>Volatility in vehicle price according to the changes in the market</td>
<td>Heavy Rail</td>
<td>VEHICLES</td>
</tr>
<tr>
<td>3</td>
<td>Cost overrun in design phase because of extra time required for the details of plans and specifications</td>
<td>Final Design</td>
<td>PROJECT DESIGN</td>
</tr>
<tr>
<td>4</td>
<td>Cost overrun in construction management resulting from extra time needed to supervise the night shifts</td>
<td>Construction Admin. &amp; Mgmt.</td>
<td>PROFESSIONAL SERVICES</td>
</tr>
<tr>
<td>5</td>
<td>Exposure to more hazardous material during construction than estimated</td>
<td>Hazmat Material Removal</td>
<td>SITEWORK</td>
</tr>
<tr>
<td>6</td>
<td>Encounter unexpected utilities during construction</td>
<td>Site Utilities and Utility Relocation</td>
<td>SITEWORK</td>
</tr>
</tbody>
</table>
Table below shows the budget items that will be affected by the risk factors.

Table 8.3. Corresponding Budget Items of the Identified Risk Factors (in Dollar)

<table>
<thead>
<tr>
<th>SCC Code</th>
<th>affected budget item</th>
<th>budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.07</td>
<td>Underground tunnel (guideway)</td>
<td>97,500,000</td>
</tr>
<tr>
<td>40.02</td>
<td>Site Utilities, Utility Relocation (sitework)</td>
<td>18,000,000</td>
</tr>
<tr>
<td>40.03</td>
<td>Hazmat material removal (sitework)</td>
<td>20,000,000</td>
</tr>
<tr>
<td>70.01</td>
<td>Vehicles (vehicle)</td>
<td>175,000,000</td>
</tr>
<tr>
<td>80.01&amp;80.02</td>
<td>Preliminary and final design (professional service)</td>
<td>181,000,000</td>
</tr>
<tr>
<td>80.04</td>
<td>Construction Administration &amp; Management (professional service)</td>
<td>143,000,000</td>
</tr>
</tbody>
</table>

The risk assessment team has estimated the cost range and probability of occurrence for each of these risk factors (Table 8.4). The probability of occurrence is modeled by Bernoulli distribution and the impact for each risk is modeled by a triangular distribution. Decision makers can simply estimate a minimum, maximum and a most likely value for each risk item and use triangular distribution to depict them (Parsons et al 2004). The effect of each risk factor on the relevant budget items are found as the product of the defined triangular distribution and the estimate of budget item and then added up by using Monte Carlo simulation.
Table 8.4. The Impact and Probability Distribution of Transferable Risk Factors

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Probability</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>unforeseen cut or fill due to different site conditions (DSC)</td>
<td>$P(x = 1) = 0.3$</td>
<td>Triang(0.1,0.25,0.35)</td>
</tr>
<tr>
<td>volatility in vehicle price according to the changes in the market</td>
<td>$P(x = 1) = 0.7$</td>
<td>Triang(0.1,0.15,0.3)</td>
</tr>
<tr>
<td>cost overrun in design phase because of extra time required for the details of plans and specifications</td>
<td>$P(x = 1) = 0.3$</td>
<td>Triang(0.1,0.25,0.35)</td>
</tr>
<tr>
<td>cost overrun in construction management resulting from extra time needed to supervise the night shifts</td>
<td>$P(x = 1) = 0.2$</td>
<td>Triang(0.1,0.2,0.3)</td>
</tr>
<tr>
<td>Exposure to more hazardous material during construction than estimated</td>
<td>$P(x = 1) = 0.5$</td>
<td>Triang(0.3,0.5,0.65)</td>
</tr>
<tr>
<td>Encounter unexpected utilities during construction</td>
<td>$P(x = 1) = 0.3$</td>
<td>Triang(0.3,0.4,0.6)</td>
</tr>
</tbody>
</table>

The total cost of these risks should be added to the project budget. The calculations are done in an Excel™ spreadsheet using @Risk™ add-in software for simulation. In order to achieve a 90% confidence level for the project budget and assuming that the only uncertainty in the costs is reflected in the cost of the identified risks, one can use the CDF
of the total risks (Figure 8.2). This is the total amount that should be added to the project raw budget to reach the 90% confidence level. This amount represents the project contingency in dealing with the identified risks. The total amount of contingency is found to be $97,000,000 which is 6.5% of raw PSC.

![Total Risk Impacts Distribution](image)

**Figure 8.2. The Cumulative Distribution Function of Total Risk Impacts**

The total contingency (which is calculated based on the 90%) is divided between the affected budget items in proportion to the original estimated cost of each activity (cost of each budget item over the total cost of these six budget items). After the results are calculated, the contingency value is equally divided over the duration of each of the affected budget items.

The total effects of risk factors are given in the table below.
**Table 8.5. The Total Effects of Risk Factors on Project Budget Items**

<table>
<thead>
<tr>
<th>SCC Code</th>
<th>Budget Item</th>
<th>Total Addition</th>
<th>Duration (years)</th>
<th>Annual Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.07</td>
<td>underground excavation (guideway)</td>
<td>14,905,437</td>
<td>5</td>
<td>2981087</td>
</tr>
<tr>
<td>40.02</td>
<td>Site Utilities, Utility Relocation (sitework)</td>
<td>2,751,773</td>
<td>5</td>
<td>550,354</td>
</tr>
<tr>
<td>40.03</td>
<td>hazmat material removal (sitework)</td>
<td>3,057,526</td>
<td>5</td>
<td>611,505</td>
</tr>
<tr>
<td>70.01</td>
<td>vehicle (vehicle)</td>
<td>26,753,349</td>
<td>3</td>
<td>8,917,783</td>
</tr>
<tr>
<td>80.01&amp;80.02</td>
<td>preliminary and final design (professional service)</td>
<td>27,670,607</td>
<td>9</td>
<td>3,074,511</td>
</tr>
<tr>
<td>80.04</td>
<td>Construction Administration &amp; Management (professional service)</td>
<td>21,861,308</td>
<td>9</td>
<td>2,429,034</td>
</tr>
</tbody>
</table>

This is added to the project cash flow which was developed based on raw PSC. Using a discount rate of 7%, the Net Present Value of this cash flow is equal to $1,902,418,130.

The following table shows the project raw costs (raw PSC) in its first 9 years. The design and construction of the project is scheduled for 8 years and the last column is representing the first year of operation phase.
### Table 8.6. The Project Raw PSC in Design and Construction Phase

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost</td>
<td>53,400,000</td>
<td>68,100,000</td>
<td>66,900,000</td>
<td>97,000,000</td>
<td>299,600,000</td>
<td>409,600,000</td>
<td>381,300,000</td>
<td>204,800,000</td>
<td>85,230,000</td>
</tr>
<tr>
<td>NPV</td>
<td>49,906,542</td>
<td>59,481,177</td>
<td>54,610,328</td>
<td>74,000,836</td>
<td>213,610,659</td>
<td>272,933,775</td>
<td>237,454,477</td>
<td>119,195,465</td>
<td>46,359,473</td>
</tr>
</tbody>
</table>

**PPP Proposal**

In order to complete the PPP-PSC comparison a hypothetical PPP proposal is developed. It is assumed that the project will start operating in 6 years (vs. 8 years for the DBB). The schedule shortening capability of PPP is well-documented in the literature (Please refer to Chapter 2 and 7). The proposer is asking for the following cash flow. Although the cash flow is not based on a real PPP project, it is aimed to be reflective of common practice in projects of other kinds. For example, the owner’s participation in capital costs is similar to a case in Canada (Canada Line) in which the government paid more than 60% of its capital costs (Chapter 2). Also the annual payments to the PPP contractor is not based in the farebox or other project sources of income; it is based on availability of service and has a growth rate of 6% (Please refer to Chapter 2 for different types of PPP payments)\(^8\). A number of assumptions like the growth rate in PPP payment or savings resulted from PPP are aimed to be reflective of real PPP projects. However, the main purpose of the hypothetical project is to show the application of the method and these assumptions

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\(^8\) There is a lot of uncertainty embedded in the project revenue (ridership, commissioning, cost of energy, *etc*.). Nevertheless, this dissertation does not discuss about the most appropriate PPP payment method.
should not be taken as common trend in PPP transit projects (lack of PPP projects made it impossible to deduct these rates from a set of projects). It is assumed that the project capital cost (design and construction) is 95% of the PSC raw estimate ($1.6 billion). In other words, the PPP initial costs would be 5% less than PSC. This assumption is based on the cost savings achieved in other finished PPP projects (Please refer to Chapter 2). It is also assumed that the owner will participate in project capital cost by paying 60% of it over 3 years of construction. So the owner would pay 

\[(0.95 \times 0.60 \times 1,600,000,000) \div 3 = $304,000,000\] 

to the contractor in years 4, 5, and 6.

First 3 years: no payment required.

Years 4, 5, and 6: 60% of the total construction costs will be paid in these three years.

Year 7: Payment of $100,000,000 and there after the payment increases by a rate of 4% for 30 years of operation.

Figure 8.3. Cashflow of Owner’s Payment in PPP Option
The NPV of this cash flow (PPP cost to the owner) using the same discount rate (7%) would be $1,926,002,448.

Comparing this number with $1,902,418,130 (the NPV of risk-adjusted PSC) shows that based on PSC-PPP comparison, the PSC option should be selected and the best delivery method for this project would be a Design-Bid-Build. It should be again mentioned that the option with smaller amount of NPV should be selected as here the numbers are all owner’s payments.

The small difference between PPP and PSC is not uncommon (Grimsey et al 2005a). The difference between the NPV of the two options (PPP and PSC) in this hypothetical case is almost 1.3%. A major reason for the similarity of this case and other real cases is the reasonable assumptions made for PPP proposal and the PSC option. However, the PPP-PSC comparison does not assist the decision maker in a way that the decision can be made solely based on this comparison. As it was mentioned, the decision maker should again consider the qualitative factors that were proposed for “before advertisement” evaluation of PPP. The level of completion, the importance of risk transferring, the importance of private sector participation in project finance, and the federal support of a PPP project are among the factors that may finally direct the decision makers. It should be mentioned that the calculation of PSC and comparing it with the PPP proposals is a solid ground for a decision and the advantages of this comparison should not be ignored due to the small differences between the calculated NPVs in some cases.
Another solution for this challenge is to conduct a sensitivity analysis to test how robust the decision may be to the changes in some of the financial assumptions. The sensitivity analysis can even include project construction schedule and project life cycle.

**Sensitivity Analysis**

A limited sensitivity analysis was performed on the total PSC costs (before risk adjustment) to understand the effect of these movements in these cost items on the total project cost. Each time one variable was changed while keeping the rest of the variables unchanged. Table 8.7 illustrates the results of this analysis. For example a 15% decrease in capital costs would result in a raw PSC of $1,673,348,433.90.

<table>
<thead>
<tr>
<th></th>
<th>Capital Costs</th>
<th>O&amp;M Costs</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>-15%</td>
<td>1,673,348,433.90</td>
<td>1,723,267,853.55</td>
<td>2,067,731,084.12</td>
</tr>
<tr>
<td>-10%</td>
<td>1,727,568,557.27</td>
<td>1,760,848,170.37</td>
<td>1,985,227,407.39</td>
</tr>
<tr>
<td>-5%</td>
<td>1,781,788,680.65</td>
<td>1,798,428,487.20</td>
<td>1,908,140,369.02</td>
</tr>
<tr>
<td>0%</td>
<td>1,836,008,804.03</td>
<td>1,836,008,804.03</td>
<td>1,836,008,804.03</td>
</tr>
<tr>
<td>5%</td>
<td>1,890,228,927.40</td>
<td>1,873,589,120.85</td>
<td>1,768,416,567.03</td>
</tr>
<tr>
<td>10%</td>
<td>1,944,449,050.78</td>
<td>1,911,169,437.68</td>
<td>1,704,987,757.46</td>
</tr>
<tr>
<td>15%</td>
<td>1,998,669,174.15</td>
<td>1,948,749,754.50</td>
<td>1,645,382,481.70</td>
</tr>
</tbody>
</table>

Table 8.7. Sensitivity Analysis of PSC Raw Costs
Figure 8.4. Spider Diagram for Sensitivity Analysis of PSC Raw Costs

The spider diagram of Figure 8.4 shows that the discount rate is the most influential factor on raw PSC. Also it shows that the sensitivity of the results to O&M costs and capital costs is almost the same. In order to analyze the sensitivity of the decision to changes in some of the assumptions, a sensitivity analysis was conducted to evaluate the change in the difference between the NPV of PPP and NPV of PSC by changing the discount rate and capital costs. The changes are implemented in both scenarios; for example decrease in construction costs are assumed to happen in PPP as well as the PSC option. This way the comparison would be based on similar inputs. The table below illustrates the results. As it can be seen in the table, almost 5% change in discount rate or capital costs changes the decision and makes the results switch from PPP to PSC.
Table 8.8. Sensitivity Analysis of PPP-PSC Comparison

<table>
<thead>
<tr>
<th>Capital Costs</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>-15%</td>
<td>98,520,690</td>
</tr>
<tr>
<td>-10%</td>
<td>73,541,899</td>
</tr>
<tr>
<td>-5%</td>
<td>48,563,509</td>
</tr>
<tr>
<td>0%</td>
<td>23,584,318</td>
</tr>
<tr>
<td>5%</td>
<td>-1,394,473</td>
</tr>
<tr>
<td>10%</td>
<td>-26,373,264</td>
</tr>
<tr>
<td>15%</td>
<td>-51,373,264</td>
</tr>
</tbody>
</table>

The spider diagram in Figure 8.5 illustrates the same conclusion presented in the discount rate discussion of this chapter. It illustrates that a 6% increase in discount rate will change the decision (the line representing the discount rate intersects with the x-axis). The above calculations used a 7% interest rate and found the PSC option to be slightly less costly to the owner. If the interest rate increases to 7.5% the decision switches from PSC to PPP. The main reason for that is the private sector participation in upfront costs (compared to PSC where the owner should pay all the capital costs) and the effect of an increase in the interest rate on lowering the future payments to the private sector. It should be noted that the annual cost of the project operation is less in the PSC case (i.e. payments to the PPP contractor is more than project O&M costs). This difference combined with the change in the discount rate plays an important role in selecting between PPP and PSC. The same is true for capital costs. An increase of 5% in the capital costs ($75,000,000) would change the decision too. In other words, a 5% increase in the capital costs makes the PPP a less costly option. It should be again mentioned that the sensitivity of the decision to the financial parameters is case-based and the results of this case study should not be interpreted as common trends in PPP projects.
Figure 8.5. Spider Diagram for Sensitivity Analysis of PPP-PSC Comparison

Conclusion

This chapter showed the application of PSC-PPP comparison to a hypothetical project. It reflected the findings in the literature about the PPP projects, their financial stand point and their dependence to the public owner’s participation in capital costs as well as guaranteed revenue throughout the operation phase. The chapter applied the methods introduced in Chapter 7 for PSC calculation and its comparison with a hypothetical PPP proposal. The chapter attempted to show the details of this comparison by providing a set of reasonable assumptions for discount rate, owner’s participation in project capital costs, guaranteed revenue, etc. The sensitivity analysis conducted at the end of the chapter also gave a better understanding of the robustness of the results to changes. A major finding of sensitivity analysis was the significant effect of discount rate on the final outcome of the PSC-PPP comparison.
Chapter 9. System Validation

Introduction

The last step in developing a decision support system (DSS) is validation. A DSS is not reliable unless it is validated. The output of a DSS is a project delivery method which is claimed to be the most appropriate option given the conditions of the project under consideration. Therefore one can assume that applying the proposed DSS to a finished project and comparing its suggested PDM with the one actually used for that project would solve the validation challenge: if the output of DSS matches the PDM actually used for the project, it is valid and if not the DSS is invalid. This approach has a basic flaw in its assumption and that is giving full credit to the actual PDM selected for the project. There is always a chance that the selected PDM for the project was not the best option and the decision makers had not followed any systematic approach towards PDM selection. Therefore any difference or similarity between the result of DSS and the actual choice of PDM in a finished project is meaningless.

Ginzberg (1978) believes that the DSS evaluation problem is “thorny”. He refers to the fact that it is difficult (if even possible) to give a value to the promised outcome of using a developed DSS (e.g. better decision making). There are few ways, however, to validate a proposed DSS. Interviews and criticism of the proposed DSS is among the most common methods (Yin 1984, TCRP 2009). This dissertation has mainly used this method to validate the proposed DSS.
Validation Methods

The proposed decision support system was validated as a requisite model. “A model is requisite if its form and content are sufficient to solve the problem” (Phillips 1984). The importance of generating a requisite model comes from the fact that this type of model includes all the influencing factors and does not leave out a critical factor. The DSS developer usually contributes to the form of the model while the problem owners’ participation is mainly in the contents of the model. The form of the model includes its structure (weighted matrix, decision tree, influence diagram, etc.) and its generic elements (outcomes, consequences, etc.). The content of the model (weights, assessment of probabilities, element linkages, etc.) should be based on the participants’ understanding of the problem itself. If the efforts of the DSS developer and the problem owners are well coordinated and both sides perform their roles, a requisite model is more likely to be achieved. “A requisite model is more likely to be adequate if problem owners contributing to its development represent a variety of views and if the specialist [model developer] can provide a neutral perspective and setting” (Phillips 1984). In order to develop a requisite model, Ginzberg (1978) suggests that a DSS developer should interview the future users of the DSS (i.e. current decision makers) to document their needs and also collect and analyze the existing information and state of practice.

A requisite model is inherently conditional “on structure, on current information, on present value-judgments, and the problem owners” because by definition “a model is requisite only when no new intuitions emerge about the problem” (Phillips 1984). So changes in information and other conditions may render a model not to be requisite any longer.
On the other hand, there is no benchmark to compare the results of the decision support system with. Phillips’s (1984) suggestion that the validity of the decision support system should be judged by the coherence of the decision process and not by the consequences best fits to this type of research effort. As another researcher (Oyetunji 2001) in the same field observes “production of correct results could not be used as the basis for validating the procedure and the tool [decision support system] developed” in a research. The PDM chosen for a real project is not necessarily the best one for that project so any difference between the results of the proposed decision support system and the real case is per se meaningless.

Facing these challenges, the approach used to validate the proposed decision support system was to compare the results of the system with “the holistic judgment of the people” (Phillips 1984). In other words, the system should be introduced to the professionals who are involved in decision making on the problem under consideration (selecting an appropriate PDM in this case) and their feedbacks after reviewing the system should be collected and analyzed. This way, the sufficiency of the system in terms of including all the influential factors on decision as well as all the possible options to choose from, is tested.

At the same time the structure of the decision support system is evaluated and consistency of the results given similar input information is studied. In order to achieve a validated DSS, the problem owners (transit agencies) were fully involved in the DSS development process through interviews and follow-up communications. Also, the completed system was presented to professionals to obtain their judgment. The following
Construct validity: the case study data collection and interviews were first submitted to
the TCRP panel to ensure that correct operational measures were used. This research
included multiple sources of evidence by interviewing more than one expert in each
transit agency, as well as having the experts review the key information included in the
case study reports. This part was done for the conventional PDM selection (Tier 1, 2, and
3).

Internal validity: A draft of the Tier 1 and 2 decision tool (PPP excluded) was applied
by a professional to a project that was not included in the case study data collection to
determine that the decision tool could be applied outside the universe formed by the case
study projects.

After adding the PPP part to the decision support system tool, the whole system was
again checked internally by applying it to a quasi-hypothetical project. This application
shows the details of the system as well as its applicability. It also helped fine-tuning the
DSS. However, the results of the application should not be interpreted as if the developed
DSS is in favor of a particular PDM or even promoting the use of an alternative PDM
instead of traditional DBB. The results of this application were provided in Chapter 8 of
this dissertation.

External validity: A validation workshop was conducted at the 2007 DBIA
Transportation Conference in Minneapolis and was used to confirm the findings from the
case studies. Input from the workshop helped to focus the research on the delivery
methods (PPP excluded) covered by the decision tool. Once the tool had been developed it was given to four case study agencies who were asked to run through the process and give comments on the system for its improvement. The feedbacks received from these agencies are included in the following part. As another step and after the inclusion of PPP, the whole system was presented to a number of professionals and their feedbacks on the system were implemented in fine-tuning the proposed system.

Results of Interviews

The interviews were done in two phases: First after the development of conventional PDM selection (TCRP Guidebook), and second after the addition of PPP and expansion of the DSS. The first set of interviews and follow-up communications focused on two main topics: 1) the set of critical issues developed in the TCRP research project, and 2) the applicability and reliability of proposed tiers (mainly Tier 1 and 2).

The Tier 1 and 2 decision tool were furnished to four of the case study agencies. Each agency was asked to apply the tool to a specific project that was either upcoming or had been completed. The purpose for this suggestion was that the selection system works best when the user can carefully define project objectives and goals. If the agencies had a specific project in mind they would be in a position to better define project characteristics and goals. Additionally, each agency was asked to rate the effectiveness of the tool in the following categories:

- Comprehensiveness
- Clarity
- Applicability to real projects
Contribution to resulting in a transparent and defensible decision

Overall satisfaction

In all four cases, the DSS was deemed to be valid. No unsatisfactory ratings were recorded. The specific adjectival evaluations in the specific categories are as follows:

- Comprehensiveness: 3 excellent; 1 very good
- Clarity: 4 very good
- Applicability to real projects: 3 excellent; 1 very good
- Contribution to decision: 2 excellent; 1 very good; 1 good
- Overall satisfaction: 3 excellent; 1 good

Overall comments regarding the validity of the tool from each of the four agencies show that for agencies with DBB, CMR, and DB experience the DSS is “a fine tool”. A major advantage of the suggested DSS mentioned by most of the agencies was the list of issues with advantages/disadvantage analysis. Also, the discipline of the Tier 2 analysis was found to be “a good way to stress the most important factors for the job under study.”

Thus, the Tier 1 and 2 PDM decision tool framework is found to be valid in accordance with the procedures established by the research team and approved by the TCRP oversight panel. Another finding of the validation process was that in all cases, there remained no ambiguity on the choice of PDM after going through the first two tiers. Because of this, the validation and testing of Tier 3 could not be accomplished in the same way.
In the second step of interviews, the PPP section added to the DSS was evaluated by another group of experts who were familiar with the characteristics of this delivery method, its usefulness and advantages as well as its limits and disadvantages. The interviewees covered professionals in consulting companies, FTA employees, and National Council of Public-Private Partnerships (NCPPP). The total number of responses was 8. Inclusion of FTA employees in the interviews was to reflect the general impression of the federal government about PPP. NCPPP is the most active group of professionals that are involved in PPP training seminars. Interviews with some consulting companies helped the research to understand the state of practice in these leading companies that assist the decision makers. Also an interview with an expert who was involved in the UK transit PFI projects presented some of the international approaches towards PPP. The interviewees were first asked about the definition of PPP. The results of this question were included in Chapter 2. The interviewees were asked whether or not they have been involved or at least been informed of a transit PPP project in the US. The responses to this question were based on the definition of PPP chosen by each interviewee. Nevertheless, the responses did not introduce any transit project in which the private sector was sharing project financing as well as its risks. The interviewees were also asked to comment on the comprehensiveness of the pre-bidding evaluation phase of the PPP and to evaluate the set of factors proposed in this DSS. The result of this evaluation should show whether or not that part of the DSS is requisite. The following table depicts the summary result of the interviews.
Table 9.1. The Summary of Interviews about PPP Pre-bidding Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Consultant</th>
<th>FTA</th>
<th>FTA</th>
<th>FTA</th>
<th>NCPPP</th>
<th>Consultant</th>
<th>Consultant</th>
<th>Consultant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project size</td>
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<td>•</td>
<td>•</td>
<td>*</td>
<td>•</td>
<td>*</td>
<td>•</td>
</tr>
<tr>
<td>Investment environment</td>
<td>O</td>
<td>*</td>
<td>O</td>
<td>*</td>
<td>•</td>
<td>O</td>
<td>*</td>
<td>O</td>
</tr>
<tr>
<td>Project viability</td>
<td>•</td>
<td>—</td>
<td>O</td>
<td>•</td>
<td>*</td>
<td>•</td>
<td>*</td>
<td>•</td>
</tr>
<tr>
<td>Private sector capability</td>
<td>•</td>
<td>O</td>
<td>*</td>
<td>—</td>
<td>*</td>
<td>•</td>
<td>*</td>
<td>O</td>
</tr>
<tr>
<td>Risk allocation</td>
<td>•</td>
<td>*</td>
<td>•</td>
<td>•</td>
<td>*</td>
<td>•</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Competency of public agency</td>
<td>O</td>
<td>O</td>
<td>*</td>
<td>O</td>
<td>O</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Potentials for improvement in</td>
<td>•</td>
<td>*</td>
<td>—</td>
<td>•</td>
<td>•</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Value for Money</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of performance</td>
<td>*</td>
<td>*</td>
<td>•</td>
<td>—</td>
<td>•</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Specification</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>O</th>
<th>very important</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>important</td>
</tr>
<tr>
<td>•</td>
<td>almost important</td>
</tr>
<tr>
<td>—</td>
<td>not important</td>
</tr>
<tr>
<td></td>
<td>no comments</td>
</tr>
</tbody>
</table>

Two of the interviewees added a similar factor to the list which was political/public support of the project. One of them believed that a PPP “will die” without a strong support of the public. Referring to the table above (Table 9.1) it is clear that the suggested set of issues is considered to be requisite by the interviewees. The “political/public support” mentioned by two interviewees is in fact embedded in another factor: “investment environment” because investment environment (as defined in Chapter 7) is not solely based on the availability and readiness of financial institutions to invest in an infrastructure project but it is also dependent on the political support for the PPP method, favorable legal atmosphere, and availability of required governmental supports of the project in terms of subsidies and grants.. Another important result of the table is illustration of the relative high importance of “competency of public agency”. This item is considered very important or important by the interviewees. One interviewee believed
that the most important factor to be considered is whether or not the government can do the project with its own sources of fund. If not, PPP becomes much more important. This issue is in fact reflected in the proposed DSS where the decision maker studies the possibility of doing the project without private funds (Please refer to Item 11 of Figure 3.2).

The whole DSS was also introduced to the interviewees and its elements and important details were mentioned and its flowchart was presented to them. This was done by conducting face-to-face interviews in Washington, D.C., New York City, and Boston. A summary of the dissertation was first sent to them; then if they were interested in participating in a one hour interview, a list of questions was sent to them. The interview was structured based on this questionnaire and the discussions were aimed at responding to these questions. They were also given the flowchart of the DSS (Figure 3.2) with limited explanations (more details were provided during the interview). They were asked whether the proposed DSS was applicable, comprehensive, clear, and consistent. All of the interviewees approved the DSS. There was a decision box in the DSS flowchart about the possible delays of PPP procurement phase. One of the interviewees suggested that the box should be eliminated because delays in the procurement phase are not specific to PPP. Two other interviewees after that agreed on the elimination. Therefore, the final version of DSS proposed in this dissertation does not have that decision box.

Another advantage of developing a DSS is learning both individual and organizational (Ginzberg 1978). A complete set of critical factors backed with a comprehensive analysis of advantages and disadvantages of conventional PDMs was the backbone of this DSS.
that was considered to be a very valuable part of the developed DSS by all of the interviewees.

Conclusion

A DSS validation has always been a major challenge for its developer. The decision makers are usually reluctant to evaluate a systematic approach to decision making simply because they pose a limitation on their flexibility during the decision making process. Some of them even do not have time or interest in reviewing an academic study on their own “expertise”. As mentioned in this chapter, a comparison of the DSS results with the outcomes of actual projects is also meaningless. This leaves the DSS developer with limited number of responses received from experts. This dissertation had the benefit of TCRP support and could involve several transit agencies and experts in the validation process. The results of structured interviews and application of the DSS to a hypothetical case showed that the critical factors introduced in this dissertation cover all the aspects of PDM selection and the flow of the decision and the consequence of actions are clear and applicable and will result in defensible and consistent answers.
Chapter 10. Conclusion

Summary Conclusions
This dissertation provides a comprehensive solution for a common challenge faced by the owners of new transit projects when they select a project delivery method (PDM) for their projects. The delivery method selected should help the owner to achieve their project goals and objectives in an efficient and cost-effective way. A comprehensive study should include all the available PDMs and all the qualitative and quantitative characteristics of the project that may be influenced by the delivery method option. The proposed decision support system (DSS) covered all aspects of a transit project and developed a list of critical issues that affect the choice of project delivery. The proposed DSS helps owners to assess their options in terms of financing as well as delivering the project. The dissertation included all the available PDMs, i.e. DBB, DB, CMR, and PPP.

A requisite well-structured decision making process was the foundation of the proposed framework for this decision aid tool. Several interviews and case studies were conducted to collect relevant information on the state of practice in the US transit industry.

The proposed decision support system enables the transit agencies to review the available options and select a PDM that facilitates the achievement of project goals. It also promotes the importance of risk studies in transit projects and in project delivery method selection. Highlighting the financial aspects of PDM selection is another core element of this dissertation in which some concepts such as Value for Money and Public Sector Comparator were explained and incorporated.
Advantages of the Proposed Decision Tool

Project delivery method is the framework of all the project stakeholders’ relations and responsibilities, so a substantial mistake in the delivery method selection may cost the owner a drastic failure in the project. The analysis of PDM selection demands an understanding of the advantages and disadvantages of each PDM in achieving the project success. This research sheds light on the frequently subjective decision of PDM selection and makes it more systematic and defensible. It provides answers to some questions such as:

- Can a project with insufficient revenue generation be a candidate of PPP?
- How should the owner compare PPP with the traditional DBB while the financial agreements and risk shares are extremely different in these two methods?
- How to make sure that PPP is the most beneficial delivery method for the public?
- How should the owner decide on the delivery methods effects on time and cost of the project when the design and specifications are not ready?

In order to address those questions a decision support system for delivery method selection in the transit projects was developed in this dissertation. This system includes DBB, DB, CMR, and PPP and compares them with qualitative and quantitative approaches. The research developed a comprehensive system which is based on practical accumulated experience in this field coupled with a rigorous analytical and quantitative consideration of all relevant issues. Developing a DSS that includes PPP is a major advantage to this research. PPPs are evolving in the US and “there are no set of rules that prescribe specifically when and how these partnerships should be pursued and implemented” (NCHRP 2009). This is the first complete decision support system that
covers both conventional delivery methods as well as public-private partnership. Developing a set of critical issues to be considered for project delivery method selection in transit is also developed in this research for the first time. Application of several analytical concepts such as quantitative risk analysis, value for money, and public sector comparator is another characteristic of the proposed decision support system.

**Dissertation Contributions**

The skyrocketing oil and material prices have already changed the behavior of commuters and many previously infeasible transit projects may become economically feasible while the federal government cannot fully support them financially. The option of PPP will be raised more often in this atmosphere and a complete decision support system should include this option and concentrate on economical aspects. Conducting similar research efforts for highways and the recent publication of their results shows the urgency and timeliness of the research undertaken for this dissertation. For example, a recent FHWA report on International highway projects using the PPP approach concludes that “PPPs are a critically important and growing percentage of the national highway network” in the United States (FHWA 2009).

The contributions of this research are many-fold and were highlighted in different parts of this dissertation. The following is a list of the more relevant contributions of this research:

1) Development of a comprehensive decision support system for project delivery selection in the transit industry:
The most recent system available to transit agencies is the one developed in a TCRP research project (A Guidebook for the Evaluation of Project Delivery Methods 2009). The author was a contributor to that study. However, the TCRP guidebook did not cover PPP delivery method, nor did it discuss the Net Present Value (NPV) as a quantitative criterion. It also did not expand the discussion on quantitative risk approach (mainly because of the low level of complexity desired by the TCRP panel). This dissertation used the results of the TCRP system and enhanced it by adding the quantitative aspects of decision making.

2) Expanding the discussion on the advantages and the disadvantages of each delivery method with respect to a set of pertinent issues:

The literature has some sets of criteria and issues that affect the choice of project delivery method but there is no complete list of pertinent issues with definition and discussion on advantages/disadvantages of each delivery method. This dissertation introduced a complete set and expanded the discussion on advantages/disadvantages of each delivery method.

3) A tailor-made sample of Public Sector Comparator (PSC) for the transit projects:

The existing literature contains a few technical notes and guides for calculating the PSC. There are few examples of PSC application to construction projects such as hospitals outside the United States but there is no case study or example found in which the PSC is calculated for a US transit project. This dissertation includes a complete case study and provides the details of PSC calculation for a transit project.
4) Application of a comprehensive risk based approach to project delivery method selection:

The importance of project risks in decision making is clear, yet its effect and role in PDM selection has not been studied thoroughly. There have been some attempts to include risk allocation or risk management as a decision factor but a comprehensive qualitative and quantitative approach was not found in the literature. This dissertation introduced a two step process that assists the owners first use a risk allocation matrix and then the results of quantitative risk analysis in the PDM selection.

Challenges and Limitations of the Dissertation

The inherent novelty of public-private partnership and its limited application in the US projects has been a major challenge for this dissertation. As it was mentioned in Chapter 2, there has been no transit project being executed with a PPP method, at least in the United States\(^9\). Hence, the degree of institutional learning that has occurred is very low. Also a practical comparison between PPP and conventional methods has become impossible. At the same time the literature is not rich enough in the topics related to PPP. Most of the papers and reports are published in the UK or Australia and some of the US reports do not even have a correct definition for PPP. Lack of PPP application to transportation projects also made the financial calculations of public sector comparator challenging but also novel and a contribution to the existing body of knowledge.

Another major challenge for any research on decision support systems is the validation process. Only a validated DSS should be trusted by the decision makers and academic

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\(^9\) Washington, Dulles Metrorail, although called a PPP, does not contain the element of financing, as required by our definition to qualify as a PPP project.
researchers. A fundamental challenge in validating the DSS for PDM selection is to find experts and professionals who would accept reviewing and criticizing the developed system. As the proposed DSS should be applied by some decision makers on higher levels of hierarchy in transit agencies and consulting companies, this issue becomes a real challenge for an academic researcher. The only way that the validation process was completed in this dissertation was the support of TCRP funded research (TCRP 2009). The TCRP panel and several interviewees from 5 different agencies (involved in 9 projects) reviewed the three tiers and the set of critical issues and gave feedback to the research team. Some of them also assisted the author by reviewing the complete DSS and made the validation process possible (Chapter 9).

Another challenge in this dissertation was precise scope definition. While this research focused on project delivery methods, it did not take into account some related concepts to PDMs, such as payment methods, procurement methods, management methods, etc. Chapter 2 clearly defined the terms and limited the scope of the research to project delivery methods. Nonetheless, one can always claim that inclusion of procurement methods, payment methods, etc. will result in a more complete DSS and this is actually one scope for further research efforts in this area.

A project-based comparison of the performance of PDMs is almost impossible simply because there are no two similar projects executed with two different PDMs. This issue limits the research efforts. One way to overcome this barrier has been the comparison between groups of projects. The focus in this approach will be on a specific type of project by ignoring some differences in the characteristics of projects. For example, this
research is limited to transit projects and has compared them even if their size and location are not the same.

**Recommendations for Future Research**

This research covered all the PDMs available to the transit agencies. It also introduced a complete set of critical issues that project owners should consider for selecting an appropriate PDM. However, the scope of this research was limited to transit industry and project delivery methods. The author does not claim that the proposed DSS can be applied to other types of projects (even infrastructure projects). For example, airports have their own characteristics (security, revenue generation, *etc.*); therefore, a similar and yet different DSS was developed for those projects (ACRP 2009) in another research effort to which the author had the privilege to contribute. Based on the aforementioned discussion the recommended general topics for future research efforts are as follows:

1) Interaction and correlation between the critical factors affecting the choice of PDM. The author has studied the interaction between owner’s control over the project and the owner’s share of project risks and has published the results (Ghavamifar and Touran 2009). However, there are several other couples or groups of factors that are suitable for similar in-depth analysis.

2) Expansion of proposed DSS by including procurement and/or payment methods. There is a need to analyze the performance of the combinations of PDMs and payment (or procurement) methods such as CMR with a GMP and CMR with a fixed price.

3) Development of a tailor-made DSS for other types of projects. The DSS described in this dissertation is developed based on the characteristics of transit projects
based on case studies, interviews, and documents related to transit industry. Another research effort was conducted for airports (ACRP 2009). The literature review in Chapter 2 of this dissertation introduced some other available DSSs for building projects or highways. Yet none of them has the same level of completeness as this dissertation does. Therefore, another effort is required to expand them and generate a DSS in which all the available PDMs are considered.
Appendix A. Bibliography


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