USDOT Region V Regional University Transportation Center Final Report

NEXTRANS Project No 045PY02

Public-Private Partnerships (PPPs) in Highway Reconstruction, Rehabilitation, and Operations

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TECHNICAL SUMMARY

NEXTRANS Project No 045PY02 Final Report, October 28, 2011

Public-Private Partnerships (PPPs) in Highway Reconstruction, Rehabilitation, and Operations

Introduction

In the context of transportation, a Public-private Partnership" (PPP) is a contractual agreement established between a public agency and private sector entity often to allow for greater participation of the latter in the delivery of a transportation product (project or service). Traditionally, private sector participation has been limited to separate planning, design or construction contracts on a fee-for-service basis to deliver the product according to the public agency's designs and specifications. As demonstrated in past research and practice, there are several advantages associated with PPPs that can be tapped to enhance product delivery in the highway sector. However, as stewards of public assets, public agencies need to back any decision to enter a PPP arrangement, with justification that is defensible, comprehensive, and transparent. At the current time, most agencies do not have a set of rational guidelines to help decide, for a given project, whether to adopt PPP and which type of PPP to adopt. A decision support framework is then needed to help highway agencies choose the best innovative PPP contracting approach under a given set of project attributes. It is desired that the best approach should be selected on the basis of criteria whose relative weights can be adjusted by the decision-maker, thus indicating the need for flexibility in the decision support framework. Also, it is useful for any such framework to be demonstrated using at least one evaluation criterion.

This study first develops a multiple criteria evaluation framework for contracting approach selection, and then uses cost savings as the evaluation criterion in a case study to demonstrate the contracting approach evaluation framework. To estimate the cost savings associated with each contracting approach, the study uses statistical and econometric techniques to model the empirical statistical relationships between cost savings on one hand, and the characteristics of contracts on the other hand.

Findings

This study finds that it is feasible to apply a multiple criteria framework to identify the best contracting approach, and presents the key elements of such a framework. For each element such as weighting, scaling, and combining the impacts of a given contracting approach, the study presents a number of different analytical techniques. Then, for one of the steps of the framework, the study presents a case study to demonstrate how that step could be carried out. Specifically, the study analyzes empirical

statistical relationships between the characteristics such as contract amount, duration, and project type, of the different PPP contracts and the outcome of the evaluation criterion (cost savings). The analysis showed that there is no single contracting approach that is suitable for all types of projects. On the basis of the selected evaluation criterion (cost saving), it was found that the best contracting approach that is identified for a given set of project characteristics, is heavily influenced by certain project attributes such as the project cost, size, types of constituent activities, and expected duration. In throwing light on the empirical statistical relationships between PPP contract characteristics and their associated cost savings, this study developed material that can ultimately contribute to the building blocks for the PPP evaluation and decision support framework that was developed as part of this study.

Recommendations

The study product can be used by highway agency asset managers as a decision-support tool to identify whether to adopt a PPP for a given project, and if affirmative, the specific type of PPP that could yield the greatest net benefits to the agency. Implementing the study product is expected to provide decision-support at highway agencies who continually seek not only to infuse greater transparency and accountability in their investment decisions but also to provide cost-effective and balanced decisions that protect the use of taxpayer funds. In providing a framework for PPP evaluation, this study product can help address this issue.

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CHAPTER 1. INTRODUCTION

1.1 Study Background

Public-private partnerships (PPPs or P3s) in transportation refer to contractual agreements formed between a public agency and a private sector entity to allow for greater private sector participation in the delivery and financing of transportation projects ($OT, 2011). The Federal Highway Administration (FHWA) encourages the consideration of public-private partnerships in the development of transportation improvements. While the term PPP is relatively new, the private sector been involved in the provision of transportation infrastructure has for several decades. The extent of this involvement has been different for each phase of project development, for example, the private sector has been involved in the construction phase to a much greater extent that it has been in the planning phase. Also, for each phase, the private sector involvement has been increasing over time.

The results of a survey carried out as part of this study suggests that, at the current time, the approximate relative split between public and private participation varies widely across the different phases of highway infrastructure development (Figure 1.1). For the preliminary engineering phase (where work includes needs assessments and major corridor location studies) the survey results suggest that approximately half of the work is currently being carried out by the private sector. A similar result was observed for the phase of highway facility planning (where technical, economic, environmental feasibility and impacts are evaluated, and costs are estimated, and funding programs are developed), For the financing phase, the survey results suggest that the financing of highway development is overwhelmingly carried out by the public sector (86%); obviously, this is done mostly using fuel tax revenue. Poole 2007 notes that the private sector role in highway financing, while relatively little, is growing steadily. The results of the survey also indicated that highway design is significantly mostly carried out by the private sector; however, the public sector continues to carry out design work for facilities of

relatively smaller size and scope. At the construction phase, work is carried out overwhelmingly by the private sector as that sector is obviously more equipped, from the perspective of manpower, equipment, and organizational management, to handle work of that nature. The situation (and explanation) is similar for the highway preservation (maintenance and rehabilitation) phase; however, this phase, the public sector continues to play a significant role by carrying out routine maintenance (such as crack sealing and pothole patching) on force account basis using in-house personnel and equipment. The survey results also suggest that the public sector continues to play a dominant role in highway operations including ice control and snow removal. The monitoring of highway facilities involves manual inspections of bridges and other structures, load testing, collection of data on pavement roughness, condition, friction, and collection and management of traffic counts, classification, weight, and speed data. The conduction of this work is still dominated by the public sector, even though the private sector role continues to grow. Finally, the demolition of highway facilities, for reasons such as physical deterioration or functional inadequacy, for example, has approximately 50% split between the public and private sector, as the survey results suggest (it seems reasonable to assume that demolition of eligible large facilities is carried out part of the facility reconstruction (a phase that is dominated by the private sector).

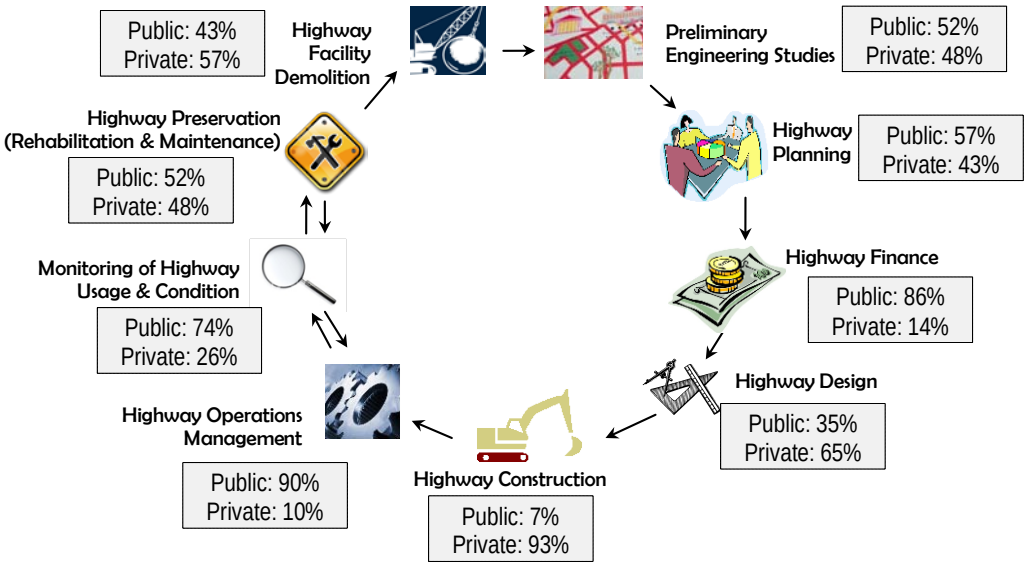


Figure 1.1 Approximate Public/Private Relative Shares

Efforts by Pradhan et al. (2011) are in progress to refine the percent splits shown in Figure 1.1, using actual data on (i) number of projects, and (ii) dollar worth of public highway projects that were carried out by the private sector and the public sector, and the evolution of each phasal split across the years.

At any phase, project delivery can be accomplished by 100% public involvement, shared public/private involvement, or 100% private involvement (Figure 1.2). A zero percent (0%) private is consistent with in-house work that is completely done by the public agency's manpower and equipment, which is the case for certain types of highway facilities and for certain phases of facility development. On the other extreme, a 100% private project delivery is consistent with publicly-owned work that is completely done by private sector resources, seems to be rare. In highway development, the most common situation for the public-private split falls in between these two extremes, where both sectors play a role in the tasks associated with the development phase in question.

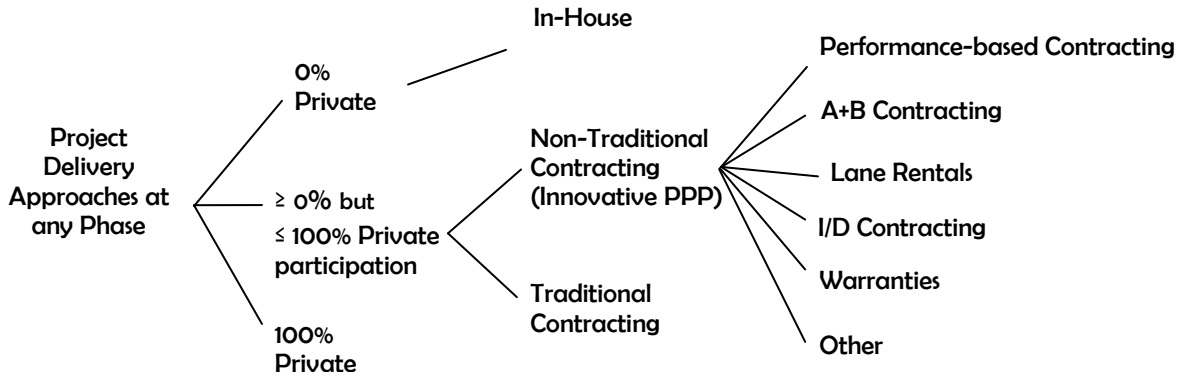


Figure 1.2 Contract Approaches at Various Shares of Private Participation

A number of dimensions of PPP applications exist in highway development projects (Figure 1.3). One dimension addresses the degree of private sector participation, which may range from 0% (work conducted completely in-house) to 100% (work conducted completely by the private sector). Another dimension is the phase of development illustrated in Figure 1.1: design only, finance only, design+finance only, design+construction only, construction+finance only, design+construct+operate only,

design+construct+operate+maintain only, etc. A few of these phase-based PPP structures are discussed in the next section. The third dimension is the status of the highway facility in question (i.e., new facility vs. existing facility). For existing facilities, the scope often is to increase the facility capacity through expansion or facility operation. Any public opposition to PPPs is least when the proposed facility is new construction and relatively high when the facility is an existing public asset. Besides these, there could be other dimensions of private sector involvement in highway project development.

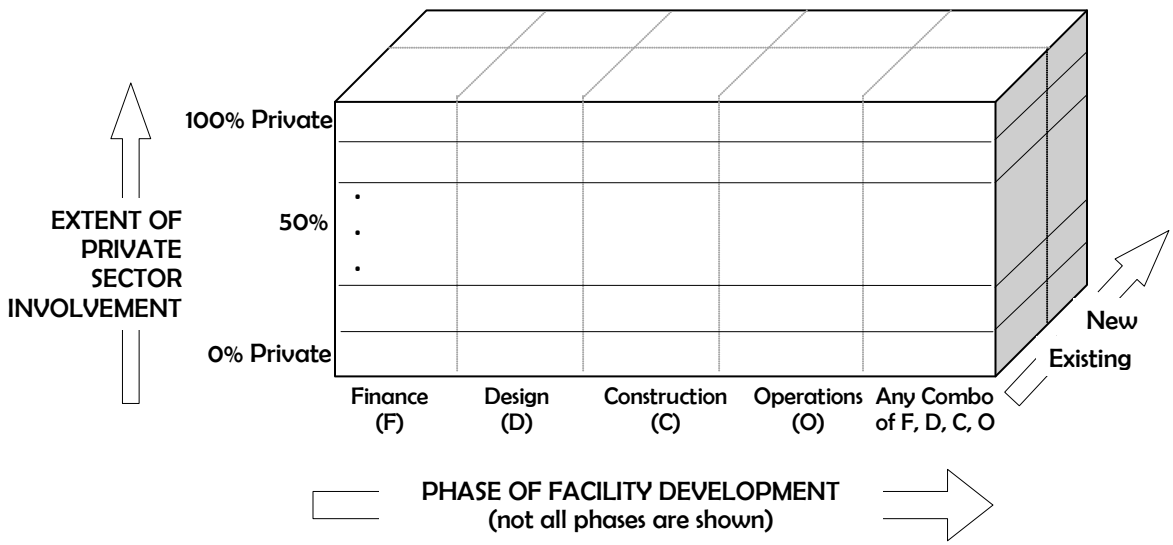


Figure 1.3 Dimensions of PPP Application in Highway Transportation

The practice of private sector participation in public facilities development, as well as the challenges and benefits, has seen a significant amount of research in the past couple of decades (Savas, 1999; Rosenau, 2000; $OT, 2011). In highway development, private sector participation has traditionally been limited to separate planning, design, or construction contracts on a fee-for-service basis, based on the public agency's specifications but has expanded in recent years. In the finance phase for example, private-sector financing through PPPs has become increasingly popular worldwide in sectors such as transportation, social infrastructure, and public utilities (Yescombe, 2007). The surge of private sector participation can probably be traced to its evident benefits, at least in the short term. As demonstrated in pilot studies and by economic theory (Grimsey and

Lewis; Savas, 1999), expanding the private sector role can yield significant benefit to the public. Specifically, increased private sector participation allows public agencies to tap private sector technical, management, and financial resources in new ways to achieve certain public agency objectives, such as greater cost and schedule certainty, supplementation of in-house staff, innovative technology applications, specialized expertise, or access to private capital. As such, some of the primary reasons for which public agencies enter into public-private partnerships include (Carpenter et al., 2003; Segal et al., 2003: (a) drawing on private sector expertise in accessing and organizing the widest range of private sector financial resources; (b) exploiting the private sector's relative advantage in providing a specialized management capability for large and complex programs; (c) accelerating the use of new technologies; (d) accelerating the implementation of high priority projects by packaging and procuring services in new ways; (e) encouraging private entrepreneurial development, ownership, and operation of highways and/or related assets; and, (f) allowing for the reduction in the size of the public agency and the substitution of private sector resources and personnel. Generally, in project management, it is desirable to allocate risks to the party that is the best equipped to manage them. As such, PPP contracts typically include incentives that reward private partners for mitigating the risk factors associated with the highway project. The private partner can expand its business opportunities in return for assuming the new or expanded responsibilities and risks.

1.2 Problem Statement

The privatization of highway development has seen some support (Samuel and Poole, 2007) and opposition (Schulman and Ridgeway, 2007). Others such as Zhang (2006) have taken different approach stating that privatization, specifically, PPP arrangements, may have net beneficial or adverse impacts depending on a number of factors related to the project and the contracting environment. As emphasized by Yescombe (2007), it is important for public agencies to consider a number of issues before adopting any specific type of PPP arrangement. At the current time, most agencies do not have a consistent framework or set of rational guidelines by which they decide whether to adopt PPP for a given project; and if the decision is to adopt a PPP, which type of PPP should be adopted.

Before such a decision can be made in a rational manner, the agency needs to develop and implement a PPP evaluation and decision-support framework that will incorporate the PPP costs and benefits for contracting arrangements at each of the different phases of highway development or a combination thereof.

In decision-making problems to select the best of several alternatives, the primary building block is the establishment of the criteria for the evaluation. In the area of highway contracting approach selection, these criteria (from the perspective of the highway agency), often includes technical, financial, economic, and environmental considerations that reflect the concerns of the agency, the highway users, and the community (Sinha and Labi, 2007). In the specific context of whether or not to privatize highway development and if affirmative, which privatization option to adopt, establishing the evaluation criteria is critical because the decision-maker seeks to identify the best option in terms of the different evaluation criteria.

In applying any such framework, the impact of each contracting approach or privatization option in terms of each evaluation criterion, is determined. However, the problem is that there are very few theoretical or empirical relationships that have been established in order to predict the impacts of each alternative in terms of say, finance, economics, safety, and the environment. From the economic perspective, for example, the expected cost savings associated with each contracting approach may be a key evaluation criterion; in that case, it will be needed to examine the empirical statistical relationships between cost savings on one hand, and the characteristics of contracts under each project delivery approach (such as PPP and traditional approaches, and in-house delivery) on the other hand.

A decision support framework is then needed to help highway agencies choose the best innovative PPP contracting approach under a given set of project attributes. It is desired that the best approach should be selected on the basis of criteria whose relative weights can be adjusted by the decision-maker, thus indicating the need for flexibility in the decision support framework. It is desired that the framework is demonstrated using at least one evaluation criterion.

1.3 Objectives of the Present Study

As stated in the preceding section, a key aspect of the evaluation framework to identify the best project delivery approach is to select the appropriate evaluation criteria and then to establish the requisite theoretical or empirical relationships in order to predict, for each alternative project delivery approach, the impacts of that alternative in terms of at least one evaluation criterion. This study seeks to use cost savings as the evaluation criterion to demonstrate the contracting approach evaluation framework as that data is readily available. Thus, an objective is to use statistical and econometric techniques to model the empirical statistical relationships between cost savings on one hand, and the characteristics of contracts under each project delivery approach (such as PPP and traditional approaches, and in-house delivery) on the other hand. The different PPPs and the in-house contracts have similar scopes of work, length, etc., so that the basis for comparison is unbiased.

The overall study objective, therefore, is to develop a framework for PPP evaluation and decision support that highway agencies can use to decide whether to adopt a PPP and if affirmative, which type of PPP to adopt for a specific project, and to demonstrate a part of the framework. The “optimal” decision is that which is generally associated with the maximum possible benefit and/or the least possible disbenefits to the agency, user, community, or any selected or preferred combination of these stakeholders.

CHAPTER 2. A REVIEW OF LITERATURE ON CONTRACTING APPROCHES

2.1 Prelude

This chapter reviews the existing literature on the subject of PPP contracting particularly on topics such as motivation for private-sector participation, PPP contracting approach definitions, issues related to traditional contracting, and the merits and demerits of alternative contracting approaches.

2.2 Motivation for Private-Sector Participation

A number of researchers including Segal et al. (2003) have identified a number of motivations, at least from the public sector perspective, for private sector participation, particularly, entering PPP contracting arrangements. The first is to gain access to capital because sources of public funding are becoming increasing limited in their adequacy and reliability. Another reason is to enhance efficiency: agencies outsource their projects in order to improve overall system efficiency through competition and specialization. Past research has shown that competitive approaches are more efficient compared to traditional single-provider approaches. Also, in cases where public agencies become part of the competition, they tend to become more efficient and provide better services in order to compete well with the private sector. The third reason is to exploit available technology: in order to increase profit, the private sector is highly motivated to seek innovative and cost-effective ways of delivering services, and this often includes the use of technology. Another motivation is to reduce cost: by including the private sector in the process, the public agency is placed in a better position to deliver their products within budget and on time; as such, agencies seeks contracting approaches that lead to a reduction of cost compared to traditional approaches for project delivery. Also, the private sector often has greater access to superior expertise and risk management techniques.

2.3 Issues with the Traditional Contracting Approach and the Need for Alternative Approaches

In the traditional contracting approach, the owner (often, the public agency) approves the design documents (which include prescriptive plans and technical specifications), and then selects an appropriate contractor to deliver the product (construct the highway). Pay items are established on a schedule of rates or quantities and detailed specifications for the construction procedures and materials for delivering the product are provided by the agency. The bids from different contractors are evaluated on the basis of several criteria such as bid price and contract period; however, the project is often awarded to the pre-qualified bidder with the lowest bid price. During the delivery of the project, the role of the agency is limited to supervision, inspection/oversight, and monitoring the construction process, as well as maintaining the constructed facility in an acceptable condition in the post-construction phase when the facility is in operation. Traditional contracting minimizes the risk to the contractor (Carpenter et al., 2003; Segal et al., 2003) because it defines all the project requirements and implicitly absolves the contractor from being responsible for unforeseen site conditions. The contractor receives payment for the work on the basis of the extent of completion of a specified amount of work, not on the quality of the work. As such, any design errors and omissions in the plans, expansion of the scope of work, and repair of defects that appear after performance-bond period or other specified period in the post-construction phase, are generally the agency's responsibility. Furthermore, because the agency typically defines the work processes and the contractor follows these procedures, traditional contracts generally tend to offer very little flexibility or motivation for the contractor to duly modify the construction processes and methods in order to accelerate a specific task or to enhance the quality of the finished product.

Traditional contracting has long been a common contracting approach used by government agencies for delivering public facilities ($OT, 2001). However, it has been found to be associated with a number of limitations (Hancher, 1999) that can be so debilitating that the agencies, on the basis of past experiences, seek alternative contracting approaches. The first of these limitations is that the traditional approach is generally slow, and thus a key motivation for seeking an alternative contracting

approaches has been the desire to reduce the overall time duration of project delivery, thereby reducing time overruns and thus the user costs of delay, congestion, and safety associated with highway work zones and the community costs of construction noise and dust.

Secondly, projects delivered via traditional contracting approaches, despite the lowering of contract costs through competitive bidding, may lead to overall higher cost because of the inherent restrictions on contractor flexibility and the absence of risk to the contractor. It can be argued that the pervasive problem of cost overrun is symptomatic of this disadvantage of traditional contracting approaches. According to the Florida Department of Transportation (FDOT) (2000), a major problem observed with the traditional contracting approach is the considerable cost overruns experienced over the designated budget. For example, FDOT experienced a 12.4 percent cost overrun and a 30.7 percent time overrun on 375 traditional low-bid contracts that were let in the 1997-98 period. While certain sources of cost overruns, such as those due to inclement weather and acts of God, are unavoidable, those due to errors in design, planning, and specifications, or problems associated with project management, are generally avoidable and could be eliminated or minimized if appropriate alternative contracting approaches were used.

Thirdly, under the traditional approach, innovative practices are stifled because the agency's prescriptive specifications and the low-bid basis for contractor selection generally do not offer any reward for design and construction process innovations or risk taking. A related limitation of traditional approaches is the inability to quickly adapt to or utilize new technologies. Innovative contracting approaches, on the other hand, provide incentives to the contractor to take more risks and responsibility in their bid to provide high quality product and service at lowest cost and within a shorter period of time (Carpenter et al., 2003). Also, alternative approaches are better positioned to exploit new and emerging technologies and techniques related to construction materials, equipment, and methods through which the contractor may be able to achieve a better product at a lower cost and in less time which result in benefits to the road user and the agency in both the short and long runs.

Fourth, for the traditional approach for contracting, it is necessary that the highway agency maintains a staff large enough to carry out the required functions such as design supervision, close inspection of the construction process, and monitoring facility condition periodically in order to address any defects. By shifting some or all of these tasks to the contractor, the agency is able to lower its staffing needs.

Finally, alternative contracting approaches can help reduce the impacts of construction projects on the community and the general public (Carpenter et al., 2003). By reducing the time taken for construction, maintenance, and rehabilitation work these approaches yield less driving delays through and around work zones and thus improved safety and productivity. In addition, by providing greater incentives and flexibility for the contractor to use technologies, materials, and techniques that reduce noise and other externalities, such as water and wetlands pollution, air quality, and socio-cultural degradation, these contracting approaches can be more beneficial to the community and to the society in general.

2.4 Contracting Approaches

Over the past 20-30 years, the landscape of delivering public project has evolved significantly. In the U.S., this transformation has been precipitated by the flexibility given to state highway agencies to experiment with innovative contracting approaches on federally-funded projects (Hancher, 1999). This section describes the different new or emerging contracting approaches used by government agencies for highway construction, maintenance, or operations. These approaches are not mutually exclusive; in other words, a given contract may be characterized by one or more of these approaches.

2.4.1. Warranty Clauses

A warranty is an assurance for the integrity of a product such that the product will have a certain minimum service life without significant defects, and that if there is any physical deficiency within that period, the product provider will replace the product or will undertake the appropriate remedial action (Singh et al., 2004). Analogies can be drawn in the area of retailing, where goods are packaged and sold with a warranty/guarantee for a certain period of time during which the product may be returned

to the retailer if found unsatisfactory. In warranty contracts, the product quality is guaranteed by the contractor to provide the prescribed performance levels over the predetermined warranty period. Thus, the contractor is required to provide maintenance for the product after it has been delivered. This may lead to potential savings in maintenance for the state agency as contractors are made to assume greater responsibility for their work and are liable for any deficiencies resulting from inferior quality materials or poor workmanship thereof. Also, it has been indicated that warranty contracts typically foster increased contractor innovation and ultimately reduce overall life-cycle costs of highway construction, rehabilitation, and maintenance. The successful use of warranties in other countries, particularly in Europe, has prompted renewed interest in warranty construction practices in the United States.

A major advantage of warranty contracting is that it is not incompatible with the traditional contracting approach. That is, a warranty clause can be added to the contracting agreement in the traditional contracting bidding documents. In contracts that have warranty provisions, the contractor is assigned responsibility for the product performance and thus is required to perform all the necessary tests to ascertain materials and workmanship quality. As a result, the use of warranties can substantially reduce the number of agency personnel required for inspecting and testing the product during and after the construction process. Under warranty contracts, higher quality of the end product is more likely than the traditional contracts because threshold levels are established by both the agency and the contractor. The contractor is responsible for repairing or replacing any work that does not meet the requirements. The contractor is granted the flexibility to use appropriate materials and construction techniques without being encumbered by the agency's specification restrictions; also the contractor is encouraged to identify and use innovative practices which often help improve product quality and reduce initial or life-cycle cost.

The requirement that contractors provide warranty for their work is not an entirely new concept. Even under the traditional contracting approach, agencies typically require a one-year performance bond covering materials and workmanship. However, longer periods (five years or more) for warranty items have not been common and are being used only in contracts specifically labeled as warranty contracts. Highway projects that

are delivered using warranty provisions have been found to be associated with higher contract amounts compared to traditional projects of similar type and scale. As such, it has been argued that with warranty contracts, agencies are expected to pay more for the same level of quality that is already expected under the traditional system. However, as demonstrated by), warranty contracts lead to considerable overall savings in the short term (five years after the completion of the construction) (Singh et al., 2006) and possibly, over the entire life-cycle, obviously due to the higher quality pavements that these contracts yield (Singh et al., 2006).

There are different types of warranties on the basis of the warranty items (coverage) and the warranty period (Figure 2.1) (Aschenbrener and DeDios, 2001).

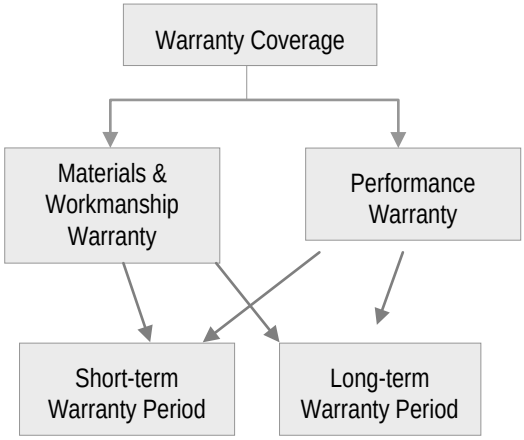


Figure 2.1 Types of Warranty

Performance warranties are typically long-term warranties that require the contractor to assume full responsibility for product performance during the warranty period. The thresholds for performance, in terms of distress parameters, are established by the owner; and the contractor is required to remedy any defects if the thresholds are not met. Performance warranties generally cover a period of at least five years after the construction of the facility.

Materials and workmanship warranties, on the other hand, require the contractor to correct defects arising from poor workmanship. Additional responsibilities for the quality of materials are shifted from the owner to the contractor. The product design is

the responsibility of the owner. Materials and workmanship warranty provisions are very short-term. There are several agencies that currently let out contracts with only workmanship warranties. Other warranty provisions also exist. For instance, in a prepaid maintenance warranty, the agency is responsible for the design, materials, and workmanship of the pavement work, and the contractor is required to follow all the specifications and to provide a guarantee of pavement quality up to a certain specified period.

Agencies continue to be sanguine about the benefits of warranty contracting. However, the industry is approaching such practices with a great deal of circumspection (ODOT, 1999). Relatively little work on the assessment of the cost-effectiveness of construction warranty projects has been carried out with field data. Warranty projects are generally more expensive than traditional projects in terms of initial agency construction costs. Investigating the benefits of warranty projects must necessarily weigh the increased project cost vis-à-vis the increased pavement quality and longevity. As states are increasingly implementing warranty contracts, a number of challenges are being identified. First, there is concern that the states may lose valuable in-house expertise as they reduce their involvement in project construction in terms of staff and testing activities (ODOT, 2000). Another issue is the required level of testing that should be included in warranty contract clauses to ensure long-term performance as most warranties provide for premature failure only. There is also some apprehension among surety companies in providing long-term bonds for large projects. Singh et al. (2004) examined whether warranties lead to overall improvement in the quality and service life of pavement, whether they lead to increased construction costs and/or increased disputes, and whether they are cost-effective in the long run.

2.4.2. Design-Build-Operate-Maintain

In design-build approaches, projects are designed and constructed by a single contractor or a partnership involving several contractors with one lead contractor (McCullouch et al., 2009). Thus, irrespective of the multiplicity of contractors each off which are associated with one or more phases, there is a single point of responsibility for the project delivery: the lead contractor. There are various design-build options: design-

build-maintain, design-build-operate-maintain (D-B-O-M or DBOM), and design-build-operate-maintain-warrant. Also, there are several ways by which a design-build contract could be specified, depending on the project size (Carpenter et al., 2003). According to the Utah Technology Transfer Center's "Innovative Contracting Best Practices Guide," design-build projects may be low-end, mid-level, or mega design. Low-end design-build projects typically involve pavement overlay or basic reconstruction projects where there is little or no room for innovative design and which are tightly time-constrained. The use of design-build helps accelerate project completion. Typically, such design-build projects are emergency projects where most of the issues related to right-of-way, utility, and environmental regulations have been resolved prior to the contracting phase, thus the design-builder easily takes over the site and carries out the work without undue pre-construction delay. In reconstruction projects, the project life is typically the main force behind the implementation of the design-build concept; thus, there often exists a maintenance or warranty provision in the form of performance specifications. Mid-level design-build projects use the design-build concept to introduce new technology to more quickly implement the project compared to the situation where the design is outsourced. Unlike the low-end design build projects, these projects can benefit from innovations in design and are usually related to bridge reconstruction or information technology systems, with a high incentive for innovation in the design as well as the construction phases. Mega design-build projects use the design-build concept in which the traditional design-bid-build process is inherently limited for handling such large projects. In the past, delivering mega projects required decomposing the project into smaller projects to accommodate funding level constraints (i.e., funding and resources do not allow for all procedures to be carried out at once). Using the design-build innovative contracting technique allows the agency to fund the project through the design-builder and to use the resources of the design-builder to supplement the existing staff strength of the agency. Mega design-build projects tend to be time-dependent and very complex in design.

The DBOM contracting approach has significant merits, including a reduction in overall project duration from design stage up to completion. The time reduction is attributable to the overlap between the design and construction or rehabilitation phases (Carpenter et al., 2003). Unlike traditional contracting where the project can only start

when the design phase is 100% complete, DBOM allows the project to commence at any design level ranging from 0 to 50%. Another merit of DBOM, the reduction in the project duration, arises from the enhanced coordination between the design and construction teams as both teams belong to the same company or partnership of companies. In DBOM, the contractor also has the ability to provide input during the design phase, and thereby an increased opportunity to use innovative designs, which has been shown to lead to fewer change orders during construction, lower costs, and faster delivery. Emzen et al. (2002), used data from 36 DBOM projects from 1992-1997 to investigate the impact of DBOM in terms of construction company business practices, employee satisfaction, safety, labor, cost, and profit margins, and concluded that DBOM project quality in the given space and time domain was no less than that of design-bid-build projects. That study also stated that the estimated reconstruction time for a seven-mile stretch of Interstate 17 would have been 900 days under the design-bid-build, but was completed in 609 days under the DBOM contracting approach. In addition to the quality- and time-related advantages, DBOM also has been shown to have overall safety benefits safety due to its lower construction period relative to that of traditional contracts) and its integration of the design and construction phases of project development.

2.4.3. Cost-Plus-Time (A+B Bidding)

The Cost-Plus-Time contracting approach, also known as A+B bidding or bi-parameter bidding, considers the bid cost and the time needed to complete the project as stated in the contractor's bid. Agency selection of the preferred contractor under this approach constitutes a bi-criteria optimization problem where the agency seeks the best alternative (contractor) on the basis of these two criteria. Recognizing that the criteria are in different units (i.e., cost in dollars and time in days), the time is converted into dollars by determining the road-user cost associated with each day of the contract duration (in dollars/day) and multiplied by the required number of days for completion, for each alternative bid. The contract is then awarded on the basis of the combined cost of contract time and cost. Where there are several evaluation criteria such as safety, quality, social impacts, and other factors (e.g., impacts on air quality, noise, ecology, and water), the problem becomes a multiple-objective optimization problem, and contracts awarded

through such a process are termed multi-parameter contracts (Carpenter et al., 2003; Herbsman et al., 1998).

2.4.4. Incentives/Disincentives (I/D)

In Incentive/Disincentive contracts, the contractor is encouraged to finish the project earlier than the time agreed upon in the contract award through the imposition of penalties for late completion and bonuses for early completion. The penalty amounts are established on the basis of road-user cost values to calculate the cost of time. For example, consider a project with I/D provisions and a road-user cost of $5,000 per day. If the contractor bids 100 days to complete a project and actually finishes in 90 days, the contractor receives an incentive of $50,000 (10 days multiplied by the road-user cost of $5,000). On the other hand, if the contractor finishes 20 days late, the contractor would have to pay to the government agency $100,000. When such provisions are used in conjunction with A+B contracts, the resulting contract approach is termed A+B+I/D contracting (Carpenter et al., 2003). These contract approaches are typically used for urban reconstruction, rehabilitation, and remediation projects of facilities where the public impact is very high, traffic volume is high, and/or the time for completion is critical.

A major advantage of the cost-plus-time and I/D contracting approach over traditional approaches is a reduction in the project overall completion time (NCHRP, 2001). This advantage is due to the incentives given to the contractor for early completion as contractors strive to avoid payment of penalties in order to increase their profit and to maintain a good public image. Another advantage is that such contracts provide an incentive and also create an auspicious environment for the contractor to use innovative construction techniques that accelerate the project.

A limitation of A+B bidding and I/D contracting approaches is the increased burden on the resources of the government agencies (Carpenter et al., 2003). Although the project is often completed in fewer days, the desire to do so may lead to the need for extended daytime work hours or even night work in order to complete the project. Also, these contracting approaches often require additional on-site monitoring efforts by the agency's inspection and testing personnel. Further, compared to traditional contracting,

the I/D and A+B contracting approaches, at the bid stage, may reduce competition as relatively few contractors, often only the larger ones, bid for such contracts.

2.4.5. Lane Rentals

In lane rental contracting, the contractor is charged a fee for occupying lanes or shoulders for the duration of the project, a scheme designed to accelerate the completion of highway projects. The charges are often based on hourly or daily rates, and the amount charged may vary with the time of day, amount of traffic, and other factors of user costs (Herbsman et al., 1998). To determine the appropriate charge for the lane rental, a road-user cost is calculated on the basis of the cost of travel delay. Herbsman et al. (1998) studied lane rentals in Europe and the U.S. and identified three types of lane rental contracts in use at the time: lane-by-lane rental where the contractor is charged for each time lanes are closed; continuous site rental which is based on a lane rental fee for each day that the lanes are occupied; and bonus/rental charge, which, like A+B bidding, awards the contract based on a combined cost of the work items cost and the cost of time, where the cost of time is based on the duration of lane closures and lane rental fees.

The advantages of the lane rental method include a reduction in project delivery time, and consequently, a reduction in its public impact. Lane rental provisions compel contractors to consider the duration of the work in their bids and to be prudent and consistent in their time management in order to reduce their costs. Not only does lane rental minimize the impact to the traveling public, but the impact to the local economy is also minimized (Carpenter et al., 2003). Similar to the case for other innovative contracting methods, there seems to be inadequate awareness of the practice of lane rentals.

2.4.6. Performance-Based Contracting (PBC)

Like most innovative contracting approaches, PBCs focus on the end product and not the process uses to develop the product. Traditionally, contracting of highway projects is based on the amount of work measured and paid for, on the basis of agreed rates for different work items. In contrast, performance-based highway contracts define the minimum physical conditions of the pavement, bridge, or traffic assets that need to be met by the contractor.

The payments to the contractor are based on how well the contractor manages to comply with the performance standards defined in the contract, rather than on the amount of work and services executed. PBC defines the final product/service and it is the responsibility of the contractor to achieve this goal. The work selection, design, construction, and delivery processes are the responsibility of the contractor. Thus, the choice and application of technology and the adoption of innovative materials, processes, and management are all left to the contractor. According to Zietlow (2005), this means that a higher risk is placed on the PBC contractor compared to the traditional contract. Nevertheless, PBCs present opportunities to increase the contractor's profit margins, especially where the use of more efficient and effective design or process or the utilization of innovation in technology or management technique can enable cost reductions while achieving the specified performance standards.

The main advantage of contracting out highway projects on the basis of end-product performance standards is the potential to produce a superior product from the outset and thus to reduce post-construction maintenance intensity, frequency, and hence, costs. Other advantages include the inherent flexibility that encourages the contractor to use innovative methods and materials to fulfill their corresponding tasks; establishment of expected minimum outcomes of the work through the performance standards; the transfer of risk for meeting the defined outcomes from the government agency to the contractor; the readiness of the contractor to respond to any road-user complaints in a timely manner and to any safety-critical problems such as fallen light poles, damaged overhead signs, storm damage, etc.; and the transfer of detailed planning, programming and budgeting functions for the highway asset in question, to the contractor.

The limitations of this contracting approach include a large monthly or annual payment independent of the amount of work performed during that time period; project management and field personnel of the government agency are still required to monitor and measure performance; the desired results might not be achieved if the performance standards do not adequately describe the desired outcomes; it is difficult to "catch up" if the performance falls behind specified levels; there is an additional cost to the government agency for identifying and producing the necessary work lists; and it is difficult to bring in another contractor to address any deficiencies that may arise.

CHAPTER 3 MULTIPLE CRITERIA FRAMEWORK FOR CONTRACT APPROACH SELECTION

3.1. Introduction

Figure 3.1(adopted from Sinha and Labi, 2007) illustrates the entire process of solving the multiple-criteria decision-making problem in contracting approach selection. This process uses several performance measures (or, evaluation criteria) to assess each candidate contracting approach (or "alternative") and finally makes a decision based on the combined impact of each approach. There are several different techniques for multi-criteria decision-making; however, most techniques involve at least one of the following steps:

(a) Establishing the evaluation criteria. First, the agency establishes the Evaluation Criteria for assessing the costs and benefits associated with each alternative contracting approach.

(b) Weighting the evaluation criteria. At this stage, the agency assigns relative weights to describe the importance of each evaluation criterion relative to the others.

(c) Scaling (normalizing or standardizing) the evaluation criteria. Since the multiple evaluation criteria often have different units, an effort is made to make them (and their different units) comparable by normalizing them to a certain scale (e.g., 0 to 100). Scaling renders the evaluation criteria to a dimensionless scale, thus making it easy to compare the different impacts and to amalgamate them by yielding an overall combined impact or desirability for each alternative approach).

(d) Amalgamating the evaluation criteria. This is the process of combining the scaled evaluation criteria to identify the best contracting approach. The outcome of amalgamation is the derivation of a single value to reflect the overall impact of a (candidate) contracting approach.

(e) Comparison and selection. After scaling and amalgamation, it is possible to compare alternative contracting approaches to select the optimal contracting approach for a given project.

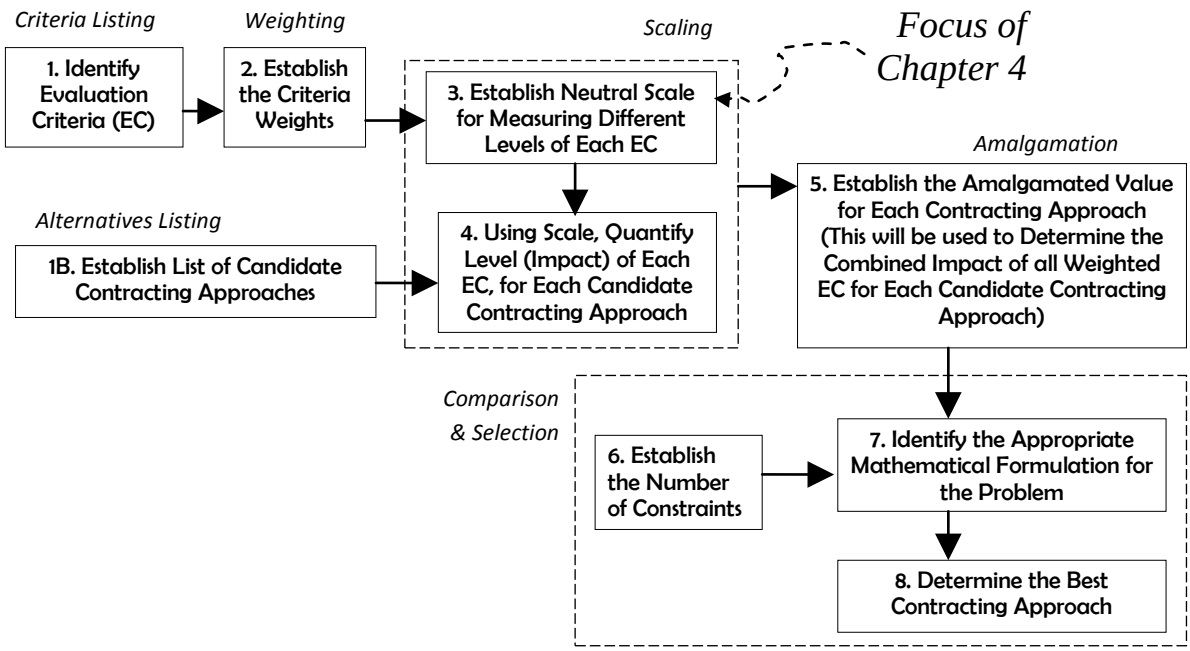


Figure 3.1 Framework for Contract Approach Selection

In certain cases, certainty and uncertainty considerations need to be taken into consideration. For a given project, the outcomes of the different contracting approaches are never known with certainty. For example, the contract duration, even for similar projects under a given contracting approach, is never the same but typically hovers around a certain average value. Thus, agencies that seek to include such variability in the analysis may need to implement appropriate methodologies to carry out optimization not only for the deterministic (certainty) but also for the probabilistic (uncertainty) scenarios. In classical literature, and indeed in real life, there are two subcases for the uncertainty scenario: the risk case, where the contracting approach outcomes in terms of the evaluation criteria have a known probability distribution, and the pure uncertainty case where the probability distributions of the outcomes are unknown. It is useful for the agency to have the capability to conduct the analysis under these cases and subcases.

In the sections below, the key steps of the contracting approach selection framework, as listed in Section 3.1 and illustrated in Figure 3.1, are described.

3.2 Evaluation Criteria for Contract Approach Selection

Performance is defined as the execution of a required function. As such, performance indicators are quantitative or qualitative measures that directly or indirectly reflect the degree to which results meet expectations or goals (Poister, 1997). The need for meaningful performance indicators in the public sector has been emphasized by the Governmental Accounting Standards Board (GASB) (1999), the National Academy of Public Administration (NAPA) (1991), and the American Society for Public Administration (ASPA) [1992]. Also, fairly recently, the U.S. Congress also passed two pieces of legislation, Public Law 101-576 and Public Law 103-62, to incorporate performance measurement into federal management processes.

For purposes of this report, an evaluation criterion is defined as a specific statement of performance goals. A performance indicator is a more specific unit to express the evaluation criterion, for example, contract duration (an evaluation criterion) may be expressed in terms of the number of days (a performance indicator). Also, cost savings (an evaluation criterion) may be expressed as the likelihood of cost overrun or cost savings or the magnitude of cost overrun or cost savings (performance indicators). A performance threshold, also referred to as a performance standard, is a specified limit of the performance indicator. For example, the agency may specify that the expected contract duration must not exceed a certain number of days. Performance thresholds (which also include cost ceilings) often constitute the key constraints in the multiple criteria decision making framework for contracting approach selection.

Zhang (2006) presented a number of factors that could be considered in best-value analysis of public–private partnership options (Table 3.1). According to Zhang (2006), the best value means the maximum achievable outcome from the development of an infrastructure project. This value includes tangible, intangible, intrinsic, and extrinsic aspects, and can be taken to reflect the concerns of the various stakeholders of the highway development process, namely, the agency, the user, and the community. Gransberg and Ellicott (1997) stated that delivery cost and time, image, aesthetics/appearance, operation and maintenance, and the managerial, safety, and environmental aspects are all elements of the best value. Also, Akintoye et al. (2003)

added that the best value emphasizes quality, efficiency/ effectiveness, and value for money and performance standards.

In selecting evaluation criteria for a given contracting approach evaluation problem, it is good practice for each individual criterion to have the following properties (Turner et al., 1996; Cambridge Systematics, 2000):

- Appropriateness. Each individual evaluation criterion should be an adequate reflection of at least one goal or objective of the transportation system action.
- Measurability. It should be possible and easy to measure each individual evaluation criterion in an objective manner and to generate the evaluation criterion levels with available analytical tools and resources. Measurement results should be within an acceptable degree of accuracy and reliability.
- Realistic. It should be possible to collect, generate, or extract reliable data relating to each individual criterion without excessive effort, cost, or time.
- Defensible. Each individual criterion should be clear and concise so that the manner of assessing and interpreting its levels can be communicated effectively within a circle of decision-makers and to stakeholders or the general public.

After the relevant evaluation criteria have been chosen, it is important to assess the entire set of criteria. The appropriateness of the set, for a given evaluation problem, can be assessed using the following considerations: (Keeney and Raiffa, 1993):

- ☐ Completeness: The set of evaluation criteria is complete if it is adequate in indicating the degree to which the overall set of goals is met.
- ☐ Operational: Since the goal of decision analysis is to help the decision-maker choose the best course of action, the evaluation criteria must be useful and meaningful to understanding the implications of alternatives and to make the problem more tractable.
- ☐ Non-redundancy: The evaluation criteria should be defined to avoid double counting of consequences.
- ☐ Minimal: The set should be as small as possible to reduce dimensionality.

Table 3.1. Best-Value Contributing Factors for PPPs in General (Zhang 2006).

BVCFs	*Remarks*
Transfer of risks related to construction, finance, and operation	Public clients take a variety of risks in traditional procurement of works and services. Transfer to the Private sector of risks that are better managed by them will increase project development efficiency.
Reducing the size of public borrowing via off-balance sheet financing	In off-balance sheet transaction, lenders look primarily to the project's revenues for repayment and to its assets as collateral for their loan. They have no recourse or only limited recourse to the general funds or assets of project sponsors
Benefits to local economy	This refers to the offers in alternative tender proposals that benefit local economic development.
Early project completion/product or service delivery	There is substantial time value to the customers related to the early availability of products/services.
Acquisition of a fully completed and operational facility	Public sector may not have various resources required for the development of a project even if they have an urgent need of it. Resources from the private sector can lead to a fully completed and operational facility.
Low project life cycle cost	The integration of finance, design, construction and operation in a single source, the concessionaire, facilitates the achievement of a low life-cycle cost of the project.
Reduced public administrative costs	Great costs are incurred in the administration of public works procured in a traditional way, especially in dealing with those risks that may be better controlled by the private sector.
Reduced disputes and claims	PPPs reverse the over-fragmentation of functions in a traditional design-bid-build contract that often leads to divergent if not confrontational agendas of the multiple participants, providing a great potential of reduced disputes and claims.
Low tariffs/tolls	The level of tariffs/tolls measures the cost to use the facilities of the project. It also determines the profit level of the concessionaire. Improved efficiency makes possible of low level of tariffs/tolls.
Long project life span	Longer life span means longer period availability of products or service. For a PPP project with a specific concession period, longer span means longer remaining service period after transfer of the project to the client.
Optimized resources utilization	This increases project development efficiency, reduces costs and makes possible better offers to the public.
Additionality (acquisition of facilities that would otherwise not be built by the public sector)	This refers to project developed as a result of unsolicited project proposals. When there is an initiative for PPPs in a public organization, private developers may go to this organization for possible PPP projects with their proposals.
Utilization of private managerial skills and technologies	Utilization of skills and technologies that are not available from the public sector enhances project development process, increases efficiency and reduces costs.
Environment friendly	Environmental issues become increasingly important, and are one of the key assessment areas in tender evaluation.
Transfer of technologies	This facilitates the operation and management of the current project beyond the concession period, and the development of new projects.
Increased project development and operation efficiencies	This makes possible low life-cycle project costs.
Improved constructability and maintainability	Constructability and maintainability are two important issues to be considered in design. Single source point in PPP projects encourages adequate attention paid to these two issues.
Additional financial sources for priority projects	This refers to the public money to be shifted from the PPP project to other important projects.
Technical innovation	A single source point encourages technical innovation and consequent improved project development.
Additional facilities/services beyond client requirements	The concessionaire may provide additional facilities beyond public client's requirements in a competitive tendering process.
Modular and repeatable design/construction	This facilitates the public client to develop similar projects in the future.

3.3 Weighting of the Evaluation Criteria

The relative weights among evaluation criteria play a very influential role on the selection of a contracting approach for a given project. Therefore, it is important to pay close attention to the investigation and choice of the most appropriate weighting schemes for the evaluation. According to Zhang (2006), the priority of the different evaluation criteria, which the author referred to as "value elements," depends on the client's business requirements and the particular attributes of the specific project under consideration, and achievability of the best value elements depends on the client's available resources.

There are a number of techniques for weighting. The equal weighting approach (i.e., same weight to each objective) is simple and straightforward and easy to implement, but it does not capture preferences among different attributes. Observer-derived weights, according to Hobbs and Meier (2000), estimate the relative weights of multiple goals by analyzing unaided subjective evaluations of the alternatives using regression analysis. For each alternative, the decision-maker is asked to assign scores to the benefits under individual goals as well as a total score on a scale of 0 to 100. A functional relationship is then established using the total score as a response variable and the scores assigned under individual goals as explanatory variables through regression analysis. The calibrated coefficients of the model thus become the relative weights of the multiple goals. Psychologists and pollsters have shown preference for the observer-derived weighting method because it yields the weights that best predict unaided opinions. Direct weighting methods (Dodgson et al., 2001) ask the decision-maker to specify numerical values directly for individual goals between 1 and 10 on an interval scale. The Analytic Hierarchy Process (AHP), which allows considering objective and subjective factors in assigning weights to multiple goals or evaluation criteria (Saaty, 1977), is based on three principles: decomposition, comparative judgments, and synthesis of priorities. The relative weights of individual decision-makers that reflect their importance are first established, and then the relative weights of individual decision-makers for the multiple or evaluation criteria are assessed.

The local priorities of the evaluation criteria with respect to each decision-maker are finally synthesized to arrive at the global priorities of the evaluation criteria. One

criticism of this technique is the rank reversal of the evaluation criteria when an extra evaluation criterion is introduced. The gamble method, which chooses a weight for one evaluation criterion at a time by asking the decision-maker to compare a "sure thing" and a "gamble," first determines which evaluation criterion is most important to move from the worst to the best possible level. Then, two situations are considered. First, the most important evaluation criterion is set at its best level, and other evaluation criteria are at their least desirable levels. Second, the chance that all evaluation criteria at their most desirable levels is set to p, and the chance that all evaluation criteria are at their worst values is set at $(1-p)$. If the two situations are equally desirable, the weight for the most important evaluation criteria will be precisely p. The same approach is repeated to derive the weights for remaining evaluation criteria with decreasing relative importance. The hypothetical probabilities for all evaluation criteria in their best or worst cases are prone to vary for different decision makers.

Zhang (2005) proposed a four-package broad set of evaluation criteria for PPP project contracting selection in general and proposed the following distribution of relative weights: financial, 40%; technical, 25%; safety, health, and environmental, 20%; and managerial 15%. These weights were established for the purpose of selecting individual contractors for a given project but could also be used in the context of the present study for selecting which contracting approach to adopt for a given project.

3.4 Scaling Techniques

In choosing the best contracting approach on the basis of multiple criteria, an agency often needs to consider an array of evaluation criteria that reflect the performance (various costs and benefits) of each candidate contracting approach. These multiple evaluation criteria have different units or metrics; for example, construction time is often measured in terms of months, cost savings in measured in dollar value, and product quality may be measured using an appropriate index for the product type such as IRI for pavements. For each candidate contracting approach, a single representative overall evaluation criterion or "desirability" is expressed for the candidate contracting approach that yields the highest value of overall desirability and is chosen as the optimal contracting approach. This section discusses a number of alternative techniques that

could be used to render all the different evaluation criteria onto the same scale, dimension, or unit. Figure 3.2 categorizes the different scaling techniques that could be used. Details of each technique are provided in the literature (Bai, et al., 2009).

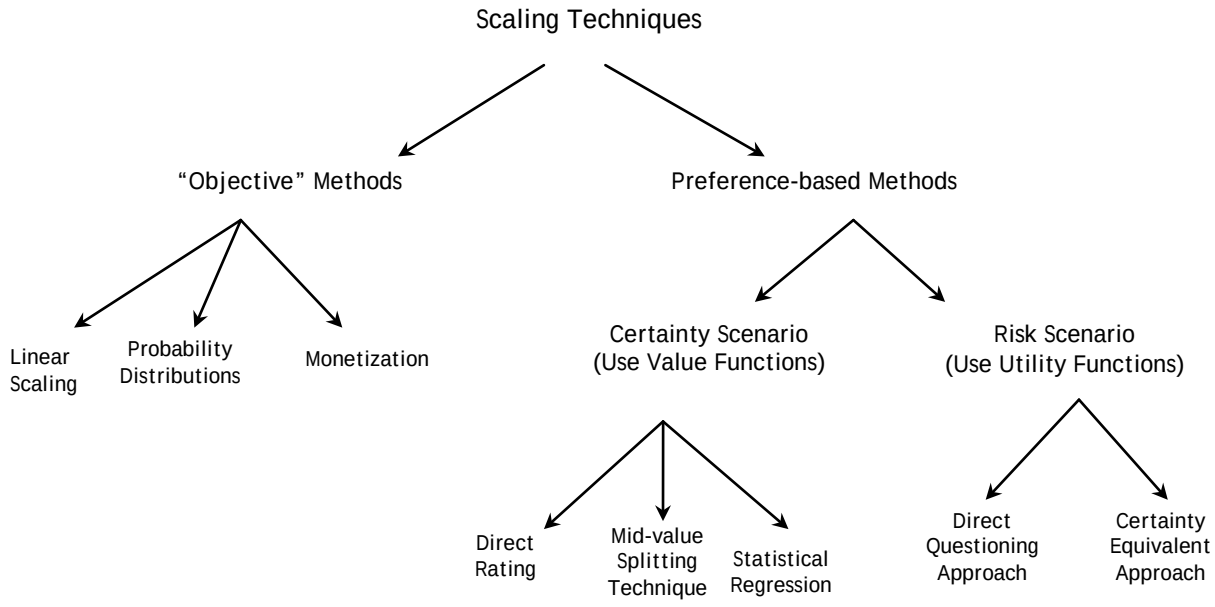


Figure 3.2 Categorization of Scaling Techniques

The scaling techniques may be categorized as follows: so-called "objective" methods and preference-based methods. In each method, scaling is carried out separately for each evaluation criterion. The results of the scaling procedure yield a function that represents the worth or desirability of the different levels of the evaluation criterion. In the simplest case, the least preferred level of the evaluation criterion is assigned a value of one (or 100%) and the worst case is assigned a value of zero. This way, it is possible to assign a scaled unit to represent the impact of any contracting approach in terms of any evaluation criterion.

The objective methods include linear scaling, probability distributions, and monetization. The preference-based methods are considered by some schools-of-thought as being subjective because they are developed on the basis of expert opinion through surveys. Scaling functions developed using preference-based methods can be categorized

into the value functions and utility functions. A utility function is considered a more general form of a value function: similar to value functions, utility functions incorporate the innate values that an agency attaches to the different levels of the evaluation criterion. Unlike value functions, utility functions incorporate an agency's attitudes toward risk (i.e., risk prone, risk neutral, or risk averse).

3.5 Amalgamation Techniques

The previous section discussed various scaling methods which render evaluation criteria with different units into one unit is commensurate across all the evaluation criteria under consideration (Bai et al., 2009). Thus, for any given candidate contracting approach, the agency can determine the dimensionless values of the impacts of the contracting approach separately for each evaluation criterion. So the question that now arises is how best to combine them to get the overall impact for the contracting approach. Combining the different impacts is necessary because the contracting approaches need to be ordered for purposes of priority ranking and also because it may be sought to determine the trade-offs among the evaluation criteria. The combination of the different impacts for each candidate in the agency's list of candidate approaches is known as amalgamation.

The literature provides details of each amalgamation method that are recommended for combining the different impacts of any given candidate contracting approach in terms of the evaluation criteria.

3.5.1 Weighted Sum Method

The weighted sum method (WSM) is probably the most commonly used by decision-makers. It uses the additive function form to obtain the final value of the overall "desirability" of each alternative (candidate contracting approach). The final value of alternative A_i can be calculated as (Fishburn, 1967; Triantaphyllou, 2000):

$$U_{A_i} = \sum_{j=1}^{n} w_j a_{ij} \quad i = 1,2,\ldots,m \qquad (3.1)$$

Where w_j is the weight of evaluation criterion j;

a_{ij} is the scaled value of evaluation criterion j for alternative i;

n is the number of evaluation criteria;

m is the number of alternative contracting approaches.

The contracting approaches with the highest U_{Ai} is the best choice.

For the WSM to be used the value of evaluation criteria must be dimensionless or have the same units (i.e., scaled values). If the scaled values are from preference-based scaling methods, the multiple evaluation criteria must be *utility independent* and *preference independent*. Utility independence means that each criterion's utility function does not depend on the levels of other evaluation criteria. Preference independence assumes the trade-offs between two evaluation criteria do not depend on the levels of other evaluation criteria. In addition, in the risk condition, the expected values of the evaluation criteria are used in Equation 3.1.

3.5.2 The Multiplicative Utility Function

Keeney and Raiffa (1976) define the multiplicative utility function of alternative A_i is defined as follows):

$$U_i = \frac{1}{k}\left(\prod_{j=1}^{n}[1+kw_j u(x_{ij})]-1\right) \qquad (3.2)$$

Where: $u(x)_{ij}$ is the utility of alternative *i* on the *j*th evaluation criterion;

w_j is the relative weight of evaluation criterion *j*;

k is a scaling constant that is determined from the equation $1+k=\prod_{j=1}^{n}(1+kw_j)$.

The multiplicative utility function is based on the premise is that all the evaluation criteria must be mutually utility independent. If $X_1, X_2, \ldots, X_n$ are the *n* criteria, we say criteria X_i is utility independent if X_i 's utility function does not depend on the levels of other criteria. Also $X_1, X_2, \ldots, X_n$ are mutually utility independent if every subset of $\{X_1, X_2, \ldots, X_n\}$ is utility independent of its complement (Keeney and Raiffa, 1976). The contracting approach alternative with the highest final utility is the most superior, for the specific project under consideration.

3.5.3 The Weighted Product Model Method

In the weighted product model (WPM) method, two candidate contracting approaches compared at a time, on the basis of the multiple evaluation criteria, to determine the superior contracting approach. First, WPM takes the ratio of the values of the levels of performance of two contracting approaches; and then uses the product model to obtain the final result upon which the agency could make a decision regarding which contracting approach is most superior or could assemble a contracting approach list ordered by superiority. The equation is: (Miller and Starr, 1969; Bridgman, 1992; Triantaphyllou, 2000):

$$r_{SL}(A_s / A_L) = \prod_{j=1}^{n} \left(\frac{x_{Sj}}{x_{Lj}}\right)^{w_j} \qquad (3.3)$$

Where x_{Sj} is level of evaluation criterion *j* for contracting approach *S;*

x_{Lj} is level of evaluation criterion *j* for contracting approach *L;*

r_{SL} = ratio between the performance impacts of *S* and *L;*

If $r_{SL} \geq 1$, contracting approach *S* is more desirable than contracting approach *L*;

If $r_{SL} = 1$, contracting approach *S* is indifferent to contracting approach *L*;

If $r_{SL} < 1$, contracting approach *L* is less desirable than contracting approach *S;*

w_i is the weight of evaluation criterion *j*.

For each alternative contracting approach under consideration, this procedure is repeated until all the of contracting approach alternatives are ranked in order of superiority. The WPM amalgamation process therefore yields a set of ratios for each contracting approach to determine how well it performs, overall, compared to the other candidate contracting approaches. Also, this method is simple and easy to use. The biggest advantage of this method is that it can use the original raw value and units of the evaluation criteria, thus obviating the need for the scaling step. Its limitations include the fact that the value of any evaluation criterion must not be equal to zero. A second limitation is that the pairwise comparison process can be onerous particularly when the number of contracting approach alternatives is large.

3.5.4 Analytic Hierarchy Process Method

The analytic hierarchy process (AHP) method, first introduced by Saaty in 1980, is one of the most popular methods used in multiple criteria decision making (MCDM). In AHP, there are two parts: a pairwise comparison and an eigenvector. In scaling, only the eigenvector part is used.

Assume the decision matrix is X as shown:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{3.4}$$

Where: x_{ij} represents the scaled value or the raw value of the evaluation criterion j of alternative contracting approach i. The matrix is then transformed as follows:

$$\begin{bmatrix} x_{11} / \sum_{i=1}^{m} x_{i1} & x_{12} / \sum_{i=1}^{m} x_{i2} & \dots & x_{1n} / \sum_{i=1}^{m} x_{in} \\ x_{21} / \sum_{i=1}^{m} x_{i1} & x_{22} / \sum_{i=1}^{m} x_{i2} & \dots & x_{2n} / \sum_{i=1}^{m} x_{in} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} / \sum_{i=1}^{m} x_{i1} & x_{m2} / \sum_{i=1}^{m} x_{i2} & \dots & x_{mn} / \sum_{i=1}^{m} x_{in} \end{bmatrix} \tag{3.5}$$

Thus, the overall desirability of contracting approach alternative i can be calculated as:

$$S_i = \sum_{k=1}^{n} w_k (x_{ik} / \sum_{j=1}^{m} x_{jk}) \tag{3.6}$$

The contracting approach alternative with the higher S_i is superior to that with a lower S_i value. Thus, the contracting approach with the highest value of S_i is the best alternative. This method can also be used to carry out a trade-off analysis between two contracting approaches on the basis of one or more evaluation criteria.

Comment. The AHP method is widely used by decision-makers in various disciplines including energy, agriculture, and public policy. In this method, the need to scale each evaluation criterion into a dimensionless unit is obviated; thus application of the method

can be relatively less demanding. However, this method becomes inaccurate when there are missing values or zero values in the decision matrix.

3.5.5 The Elimination and Choice Translating Algorithm Method

The Elimination and Choice Translating Algorithm (ELECTRE) method was first introduced in 1966 by Benayoun, et al. The basic concept underlying the ELECTRE method is to address "outranking relations" by using pairwise comparisons among alternatives to establish a set of outranking relationships. The steps of this method are as follows (Triantaphyllou, 2000):

Step1: Normalize the Decision Matrix

Use the following method to transform the value of each criterion to yield dimensionless entries:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}} \qquad (3.7)$$

Step 2: Weight the Normalized Decision Matrix

$$Y = XW = \begin{bmatrix} w_1x_{11} & w_2x_{12} & \cdots & w_nx_{1n} \\ w_1x_{21} & w_2x_{22} & \cdots & w_nx_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_1x_{m1} & w_2x_{m2} & \cdots & w_nx_{mn} \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \qquad (3.8)$$

Step 3: Determine the Concordance and Discordance Sets

Concordance Set. The concordance set of two alternatives A_S and A_L, denoted as C_{SL}, is defined as the set of all the evaluation criteria for which contracting approach A_S is preferred to A_L. That is:

$$C_{SL} = \{criterion \quad j, y_{sj} \geq y_{lj}\} \text{ for } j = 1,2,...,n \qquad (3.9)$$

The complementary subset is called *the Discordance Set*, denoted as D_{SL} (Triantaphyllou, 2000),

$$D_{SL} = \{criterion \quad j, y_{sj} < y_{lj}\} \text{ for } j = 1,2,...,n \qquad (3.10)$$

Step 4: Construct the Concordance and Discordance Matrices

The following formulae are used to calculate the entries in the concordance and discordance matrices:

$$c_{SL} = \sum_{j \in C_{sl}} w_j \text{ , for } j = 1,2,...,n \qquad (3.11)$$

When S = L, c_{SL} is not defined.

$$d_{SL} = \frac{\max_{j \in D_{sl}} \left| y_{sj} - y_{lj} \right|}{\max_{j} \left| y_{sj} - y_{lj} \right|} \qquad (3.12)$$

When S = L, d_{SL} is not defined.

Step 5: Determine the Concordance and Discordance Dominance Matrices

$$c = \frac{1}{m(m-1)} \sum_{\substack{s=1 \\ s \neq l}}^{m} \sum_{\substack{l=1 \\ l \neq s}}^{m} c_{sl} \qquad (3.13)$$

Then calculate the concordance dominance matrix F, in which the entries are defined as:

$$\begin{aligned} f_{sl} &= 1, if \quad c_{sl} \geq c, \\ f_{sl} &= 0, if \quad c_{sl} < c \end{aligned} \qquad (3.14)$$

Then

$$d = \frac{1}{m(m-1)} \sum_{\substack{k=1 \\ k \neq l}}^{m} \sum_{\substack{l=1 \\ l \neq k}}^{m} d_{kl} \qquad (3.15)$$

Calculate the concordance dominance matrix G, in which the entries are defined as:

$$\begin{aligned} g_{sl} &= 1, if \quad d_{sl} \geq d, \\ g_{sl} &= 0, if \quad d_{sl} < d \end{aligned} \qquad (3.16)$$

Step 6: Calculate the Aggregate Dominance Matrix Q

$$q_{ij} = f_{ij} \times g_{ij} \qquad (3.17)$$

In the matrix Q, if $q_{ij} = 1$, then alternative A_i dominates (is superior to) alternative A_j.

3.5.6 The Goal Programming Method of Amalgamation

Figure 3.3 presents a 3-D example of how the amalgamated impacts of a contracting approach can be found on the basis of the contracting approach impact in terms of three evaluation criteria, using goal programming.

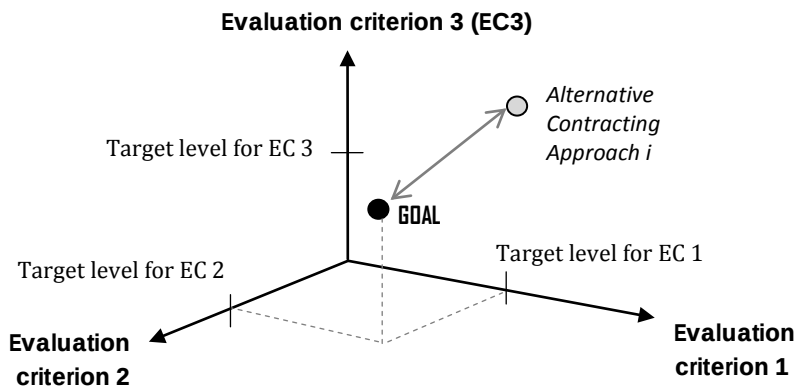


Figure 3.3: Amalgamation of Distances from Goal (for 3 Evaluation criteria)

For 1, 2, or 3 evaluation criteria, the distance of each contracting approach from the goal can be visualized and calculated using simple geometry. For four or more evaluation criteria, the evaluation problem set up cannot be visualized and an equation similar to that shown as Equation (3.22) can be used to calculate the distance of each contracting approach alternative from the established goal.

3.5.7 The Technique for Order Preference by Similarity to Ideal Solution Method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method was developed by Yoon and Hwang in 1980.The basic idea of the TOPSIS method is that the best contracting approach alternative should have the shortest distance from the ideal solution and the farthest distance from the worst solution. This method assumes that the preference structure for each evaluation criteria is monotonically decreasing or increasing, which means “the more the better” or “the fewer the better, respectively.” This method has the following steps (Triantaphyllou, 2000):

Step1: Normalize the Decision Matrix

In the decision matrix shown in Equation 3.4 of Section 3.5.4, each entry is transformed into a normalized value:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}} \tag{3.18}$$

This step has the same transformation as the ELECTRE method.

Step2: Weigh the Normalized Decision Matrix

In this step, the normalized entries in Equation 3.18 are multiplied by the relative weights of each criterion. So the normalized decision matrix becomes:

$$U = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \tag{3.19}$$

Step 3: Find the Ideal and the Worst Ideal Alternative

Assume there are two contracting approach alternatives, A^b and A^w, with decision matrix entries defined as:

$$A^b = \{a_{b1}, a_{b2}, \dots, a_{wn}\} \tag{3.20}$$

Where a_{bi} = the most preferred value among $u_{1i}, u_{2i}, \dots, u_{mi}$.

$$A^w = \{a_{w1}, a_{w2}, \dots, a_{wn}\} \tag{3.21}$$

Where a_{bi} = the least preferred value among $u_{1i}, u_{2i}, \dots, u_{mi}$.

Step 4: Calculate the Distance from the Ideal Alternative and the Worst Ideal Alternative

The distance from i^{th} alternative to the ideal alternative is defined as:

$$\mathrm{D}_{\mathrm{i}+} = \sqrt{\sum_{k=1}^{n} (u_{ik} - a_{bk})^2} \qquad (3.22)$$

The distance from i^{th} alternative to the worst alternative is defined as:

$$\mathrm{D}_{\mathrm{i}-} = \sqrt{\sum_{k=1}^{n} (u_{ik} - a_{wk})^2} \qquad (3.23)$$

Step 5: Calculate the Relative Closeness to the Ideal Alternative

The relative closeness of the ith alternative to the ideal alternative is defined as:

$$\mathrm{C}_i = \frac{D_{i-}}{D_{i+} + D_{i-}} \qquad (3.24)$$

The alternative contracting approach with the highest value of C_{i} is then identified as the best approach.

CHAPTER 4 ESTIMATING THE CONSEQUENCE OF EACH CONTRACTING APPROACH IN TERMS OF ESTABLISHED EVALUATION CRITERIA

4.1 Introduction and Scope of Case Study

This chapter implements the fourth and most intricate step in the multi-criteria decision-making framework for contracting approach selection. At this step, the consequences of each contracting approach in terms of the established evaluation criteria are quantified by using established estimation models that predict the levels of these outcomes under a given set of circumstances. A case study is utilized to illustrate this step. Binary probit and linear regression models are developed to address the likelihood that a given contracting approach will yield a certain value of the evaluation criterion (for purposes of illustration, we use the cost savings outcome as the evaluation criterion due to data availability).

The framework demonstration focuses on maintenance and rehabilitation projects. Data on the contract characteristics of the projects were collected. These projects were selected on the basis of similarity of work done, year of contract letting, and contract characteristics. The data were collected for projects that span the period 1996 to 2007. Only those projects that were completed were considered in the analyses due to the need for establishing rational comparison criteria and the availability of the final contract cost, activities, length, and construction duration. However, information for many other contracts was reviewed to gain enhanced insights of the status of various contracting approaches used in the U.S. and abroad.

4.2 Data Collection

4.2.1 Origin of the Data

This study uses data from contracts spanning the years 1996 to 2007 in the U.S. and abroad. Originally, there were 570 contracts considered in the analyses (79 Cost-Plus-Time plus Incentives/Disincentives (A+B+I/D) projects, 139 Warranty projects, 99 performance-based contracts, 76 Traditional maintenance projects, 94 Traditional rehabilitation contracts, 43 Design-Build-Operate-Maintain (DBOM), and 40 Lane Rental

projects). These contracts originated from Africa (13), Asia (five), Europe (15), Latin America (20), North America (380), and Pacific (15). Out of the 268 U.S. contracts, seven were from Texas (all PBCs); 203 from Virginia (seven I/D, 96 Warranties, 14 PBC, 85 Traditional, and one Cost-Plus-Time); 57 from Indiana (five Warranties and 52 Traditional); and Alaska (one PBC).

The country-wise distribution was as follows: three contracts originated from Argentina, nine from Australia, two from Brazil, one from Burkina Faso, one from Cambodia, six from Canada, one from Cape Verde, two from Chad, two from Colombia, one from Democratic Republic of Congo, three from Denmark, one from Egypt, one from Estonia, three from Finland, two from Guatemala, two from Honduras, one from India, one from Lithuania, one from Madagascar, two from Nepal, three from New Zealand, two from Nicaragua, two from Paraguay, three from Peru, three from the Philippines, three from Serbia and Montenegro, two from South Africa, one from Sweden, two from Tanzania, one from Thailand, three from the U.K., two from Uruguay, 374 from the U.S., one from Yemen, and two from Zambia. It should also be noted that all the contracts that originated outside the U.S. were PBCs, whereas the ones that originated in the U.S. were I/D (14), Warranties (114), PBCs (36), Traditional (181), DBOM (six), Lane Rentals (six), and Cost-Plus-Time (A+B Bidding) (17).

The data were collected and collated from the "World Bank Resource Guide – Performance-based Contracting for Preservation and Improvement of Road Assets" (http://www.worldbank.org/transport/roads/resource-guide/Country-Matix.htm); the Government of British Columbia – Ministry of Transportation – Highway Maintenance Contracts (http://www.th.gov.bc.ca/BCHighways/contracts/maintenance); the Republic of Serbia – Road Directorate (http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/bidding%20docs/serbia); the United Republic of Tanzania – Ministry of Works – Tanzania National Roads Agency (http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/bidding%20docs/tanzania); $OT – FHWA (http://www.tfhrc.gov/focus/jan05/01.htm); G. Zietlow's PBC for Road Management and Maintenance website (http://www.zietlow.com); and from other resources (Zietlow, 2005; Zietlow, 2004; Stankevich et al., 2005; Pakkala, 2002; Pakkala, 2005; PIARC-Canada, 2004; Williams, 2005; Porter 2002; Segal et al., 2003; OPPAGA,

1999 and 2003; Zietsman, 2005; VMS, 2001; JLARC, 2001; Lande, 2005; FHWA, 2002 and 2004; Michael Baker Jr. Inc., 1999; Robinson and Raynault, 2005; and Robinson et al., 2005). Also, data were collected from the departments of transportation (DOTs) of the following states: Indiana, Minnesota, Florida, Virginia, Texas, and Alaska.

The data for the case study were collected from a DOT in the Midwest region of the U.S. This agency had relatively little experience in innovative PPP; however, privatizing maintenance and rehabilitation activities has long been standard practice for this agency. In the past, the agency has let warranty contracts for pavement work that have consisted of resurfacing, restoration, rehabilitation, and reconstruction activities. Also, erosion control and mowing projects have been successfully outsourced. However, the vast majority of the agency's routine maintenance activities are carried out in-house.

4.2.2 Data Description

The data consist of the following variables:

(a) Specific origin of the contracts:

(i) Continent/Region (Africa, Asia, Europe, Latin America, Middle East, North America, Pacific). The countries were: Argentina, Australia, Brazil, Burkina Faso, Cambodia, Canada, Cape Verde, Chad, Colombia, Democratic Republic of Congo, Denmark, Egypt, Estonia, Finland, Guatemala, Honduras, India, Lithuania, Madagascar, Nepal, New Zealand , Nicaragua, Paraguay, Peru, Philippines, Serbia and Montenegro, South Africa, Sweden, Tanzania, Thailand, UK, Uruguay, USA, Yemen, and Zambia. The state or provinces were: Alberta, British Columbia, Florida, Minnesota, New South Wales, Ontario, Portsmouth, Queensland, Tasmania, Texas, Victoria, Virginia, Washington DC, Western Australia, Indiana, and Alaska.

(b) Type of contract (contracting method): These were Cost-Plus-Time (A+B Bidding); Design-Build-Operate-Maintain (DBOM); Incentives/Disincentives (I/D); Lane Rentals; Warranties; Performance-based Contracts (PBC); and Traditional contracting.

(c) Contract characteristics: This information included the duration of the contract (converted and measured in years); extensions (prolongations) of the contract's duration

(measured in years); length of the outsourced road segments incorporated in the contract (converted and measured in lane-miles); specific location of the road segments that are incorporated in the contract (Interstate Highways, or Local Roads); number of activities included in the contract.

(d) Specific road assets/activities incorporated in the contract include bridge-tunnel repair/maintenance/rehabilitation/management; crack/pothole sealing/repair; culvert/ ditches/gutters/drainage repair/maintenance/replacement; emergency facilities maintenance/response; guardrail repair/maintenance; illumination repair/maintenance; landscape repair/maintenance; litter removal; electrical/cable system repair/ maintenance; mowing; pavement repair/maintenance/rehabilitation/treatment; rest areas; shoulder repair/maintenance; traffic signs and signals; vegetation/tree control/ maintenance/removal; and all services. In many cases (e.g., some European countries and Argentina), all road assets and activities are incorporated in the contract, usually in PBCs. Instead of outsourcing road assets and activities, road sections are contracted out, where all the activities are subject to maintenance and rehabilitation. To account for some contract characteristics that may have been slightly different, the cost values were converted to $/lane-mile/year (where the duration and extension/prolongation were aggregated in the year variable) and then extrapolated to form the final amounts.

(e) Contract cost characteristics: These comprised the final cost of the contract (final cost of the outsourced contract) and in-house cost of the contract (final cost of the same outsourced contract's characteristics (number and specific activities, length, duration, etc.), when performed in-house with the government agency's resources. To account for some contract characteristics that may have been slightly different, the cost values were converted to $/lane-mile/year (where the duration and extension/prolongation were aggregated in the year variable), and then were extrapolated to form the final amounts; the engineer's estimate of the contracted projects; the cost savings; the number of bids for the outsourced contract; the highest bid for the outsourced contract; and the difference between the awarded and highest bids. The data identified and collected from relevant sources are summarized In Tables A-1 and A-2 in the Appendix. All monetary

amounts were initially were expressed in year 2006 $ (1987 base), using the Price Trends for Federal-Aid Highway Construction (FHWA, 2007; Sinha and Labi, 2007):

$$C^* = C_{ref} \times \frac{I^*}{I_{ref}}, \tag{4.1}$$

Where:

C^* is the monetary cost in any year,

C_{ref} the monetary cost in a reference year,

I^* the price index for the year of the C^*, and

I_{ref} the price index for the reference year.

4.3 Results of the Preliminary Analysis

Prior to analyzing the actual data to draw conclusions on the maintenance and rehabilitation contracting practices, a preliminary analysis is conducted. First, the PPP characteristics and international and U.S. experiences were analyzed. Next, the advantages and limitations of the examined PPP contracting methods (traditional, warranties, DBOM, A+B and I/D contracts, lane rentals, and PBCs) are presented.

In order to better describe the collected data and interpret the forthcoming econometric models' results, descriptive statistics were computed and are presented in Table 4.1. Figures 4.1 to 4.6 illustrate the duration of the contracts (measured in years) and the length of the contracts (measured in lane-miles) distributions, by contract type, region and U.S. state, respectively. In the figures, the black vertical lines illustrate the standard errors of the values presented. Figures 4.7 to 4.9 describe the distribution of the contract extension (measured in years) by contract type, region and U.S. State, respectively. In Figures 4.10 to 4.12, the in-house cost, the engineer's estimate, the final cost, and the highest bid amount by contract type, region, and U.S. state are presented. Finally, Figures 4.13 to 4.15 show the distribution of the contract cost savings (as a percentage) by contract type, specific activities, length, duration, extension, location (interstate or local roads), number of bids, and bid range.

From Table 4.1, it can be observed that the majority of contracts are traditional (40%), followed by warranty projects (25.39%) and PBCs (24.72%). A+B, I/D, DBOM, and lane rentals constitute only 3.79%, 3.12%, 1.34% and 1.34%, respectively, of the contracts studied herein.

With regard to cost characteristics, the average final cost was approximately 28.5 million $, and its standard deviation was $93.2 million. The minimum and maximum final cost amounts were 5,000 $ and approximately $1.06 billion, respectively. The average in-house cost was $34.7 million (the standard deviation was $104.1 million), the minimum was 1$2,291, and the maximum was $1.02 billion. The average amount for the engineer's estimate was $25.7 million with a standard deviation of $121.7 million, the minimum was $12,291, and the maximum was $1.16 billion. The average number of bids submitted for a contract was 2.65 bids with a standard deviation of 1.74, the minimum was one, and the maximum was10 bids. The highest bid average was $32.8 million, the standard deviation was $109.5 million, the minimum was $14,753, and the maximum was $1.2 billion. The average bid range amount was $4.4 million, the standard deviation was $22.8 million, the minimum was $0 (indicating that only one bid was submitted), and the maximum was $286 million. Taking into account all this information, especially the standard deviations of the cost amounts, it is apparent that there was a lot of variance in the data.

With regard to the contracts' characteristics, the average contract's duration was 4.44 years, with a standard deviation of 2.85 years (the minimum was two months and the maximum was 25 years). The average extension (prolongation) of the contract was 1.44 years, with a 1.55 years standard deviation, a minimum of 0 years (indicating contracts that had no extensions) and a maximum of seven years. The average length was approximately 280 lane-miles, the standard deviation was 1,543 lane-miles, the minimum was0.02 lane-miles, and the maximum was 26,098 lane-miles. In 27 contracts (approximately 6% of all cases), all activities were incorporated, whereas the majority (84.08%) of the contracts included activities on interstate road sections.

Table 4.1. Descriptive Statistics

	Mean	Std.Dev.	Skewness	Kurtosis	Minimum	Maximum	Cases
Contract Type:							
A+B	3.79%	19.11%	4.84	24.40	0	1	449
DBOM	1.34%	11.50%	8.47	72.68	0	1	449
I/D	3.12%	17.40%	5.39	30.04	0	1	449
Lane Rentals	1.34%	11.50%	8.47	72.68	0	1	449
Warranties	25.39%	43.57%	1.13	2.27	0	1	449
PBC	24.72%	43.19%	1.17	2.37	0	1	449
Traditional	40.31%	49.11%	0.39	1.15	0	1	449
Cost characteristics:							
Cost indicator Variable (1 if In-House cost, 0 if estimate)	76.79%	42.27%	-1.27	2.60	0	1	449
Final Cost of the contract (in 2006 USD)	28,417,000	93,237,500	6.97	63.01	5,000	1,059,140,000	440
In-House Cost of the contract (in 2006 USD)	34,675,600	104,102,000	5.95	45.09	7,500	1,022,080,000	337
Engineer's Estimate (in 2006 USD)	25,725,400	121,683,000	8.10	73.81	12,291	1,155,000,000	100
Cost Savings (%)	3.73%	15.35%	-2.38	17.65	-122.95%	40.00%	337
Number of Bids	2.65	1.74	1.20	4.25	1	10	434
Highest Bid	32,787,700	109,468,000	7.00	61.93	14,753.6	1,205,040,000	423
Bid Range	4,400,960	22,804,300	9.83	113.98	0	286,000,000	423
Contract characteristics:							
Contract Duration (in years)	4.44	2.85	1.23	10.33	0.16	25	441
Extension/Prolongation (in years)	1.44	1.55	1.04	3.50	0	7	435
Length (in lane-miles)	279.74	1542.53	12.57	192.63	0.02	26097.5	428
Number of activities indicator variable (1 if all activities, 0 otherwise)	6.08%	23.93%	3.67	14.48	0	1	444
Number of activities incorporated in the contract	2.02	1.77	2.49	10.11	1	10	444
Location indicator variable (1 if Interstate, 0 otherwise)	84.08%	36.63%	-1.86	4.46	0	1	446
Specific activities incorporated in the contract:							
Bridge-Tunnel Repair/Maintenance/ Management	18.24%	38.66%	1.64	3.70	0	1	444
Crack/Pothole Sealing/Repair	7.66%	26.62%	3.18	11.12	0	1	444
Culvert/Ditches/Gutters/Drainage Repair/Maintenance/Replacement	12.84%	33.49%	2.22	5.92	0	1	444
Emergency Facilities Maintenance/ Response	2.25%	14.85%	6.43	42.33	0	1	444
Guardrail Repair/Maintenance	10.36%	30.51%	2.60	7.75	0	1	444
Illumination Repair/Maintenance	6.08%	23.93%	3.67	14.48	0	1	444
Landscape Repair/Maintenance	4.50%	20.76%	4.38	20.20	0	1	444
Litter Removal	3.60%	18.66%	4.97	25.73	0	1	444
Electrical/Cable system Repair/Maintenance	17.57%	38.10%	1.70	3.90	0	1	444
Mowing	5.18%	22.19%	4.04	17.32	0	1	444
Pavement Repair/Maintenance/ Treatment	22.30%	41.67%	1.33	2.77	0	1	444
Rest Areas	12.16%	32.72%	2.31	6.35	0	1	444
Shoulder Repair/Maintenance	6.76%	25.13%	3.44	12.84	0	1	444
Traffic Signs and Signals	13.29%	33.98%	2.16	5.67	0	1	444
Vegetation/Tree Control/ Maintenance/Removal	4.05%	19.74%	4.65	22.66	0	1	444

Finally, regarding the specific activities incorporated in the contracts, 18.24% were bridge-tunnel repair/maintenance/management, 7.66% were crack/pothole sealing/repair, 12.84% were culvert/ditches/gutters/drainage repair/ maintenance/ replacement, 2.25% were emergency facilities maintenance/response, 10.36% were guardrail repair/maintenance, 6.08% were illumination repair/maintenance, 4.5% were landscape repair/maintenance, 3.6% were litter removal, 17.57% were electrical/cable system repair/maintenance, 5.18% were mowing, 22.3% were pavement repair/maintenance/treatment, 12.16% were rest areas, 6.76% were shoulder repair/maintenance, 13.29% were traffic signs and signals, and 4.05% were vegetation/tree control/maintenance/removal. As discussed, there were extreme case contracts (i.e., consisted of only one activity or included all activities).

From Figure 4.1, it can be observed that Warranties had the highest average duration (almost six years), followed by PBCs (slightly more than five years) and I/D (almost 4.5 years). However, the standard deviation of the PBCs was much higher than the Warranties' standard deviation, showing that PBCs may have much longer or shorter durations.

Figure 4.2 shows that contracts in Europe have the highest average duration (eight years); however, they also have the highest standard deviation (approximately 6.5 years). North America contracts had average contract duration of 4.5 years and a standard deviation of approximately 2.5 years.

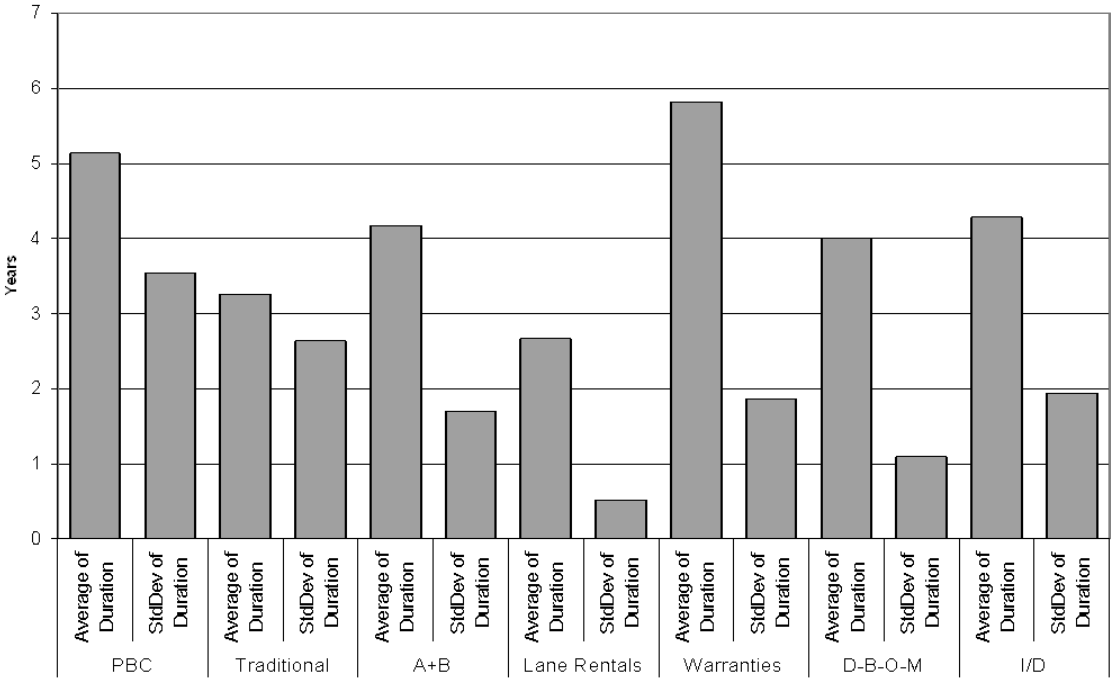


Figure 4.1. Average Contract Duration (in Years) by Contract Type

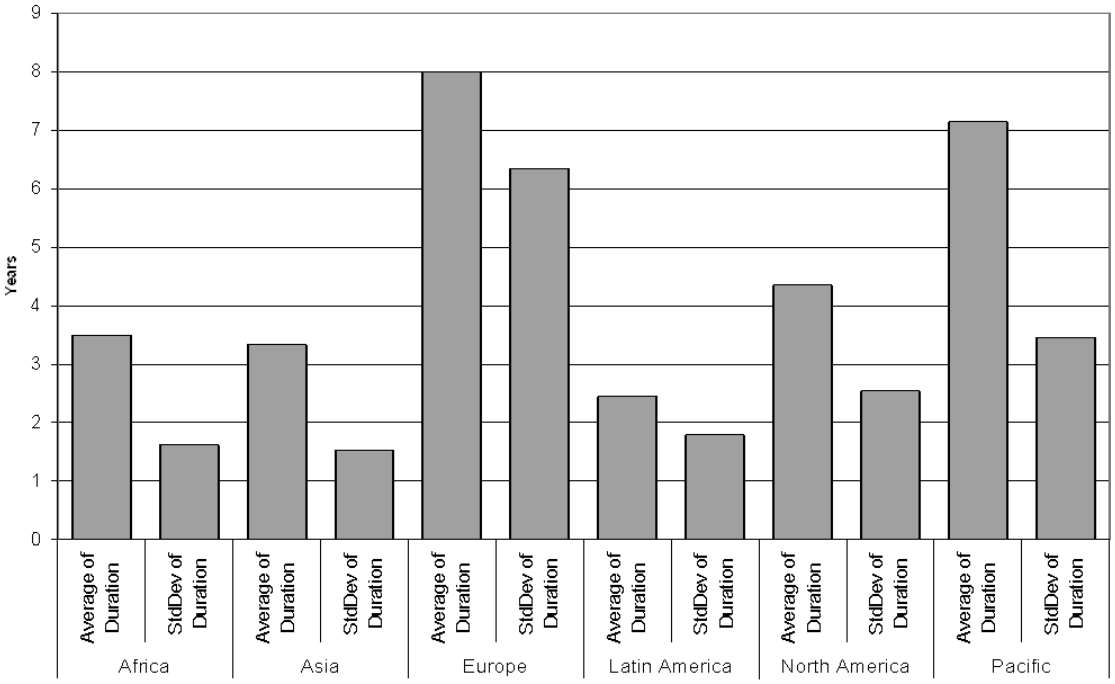


Figure 4.2. Average Contract Duration (in Years) by Region

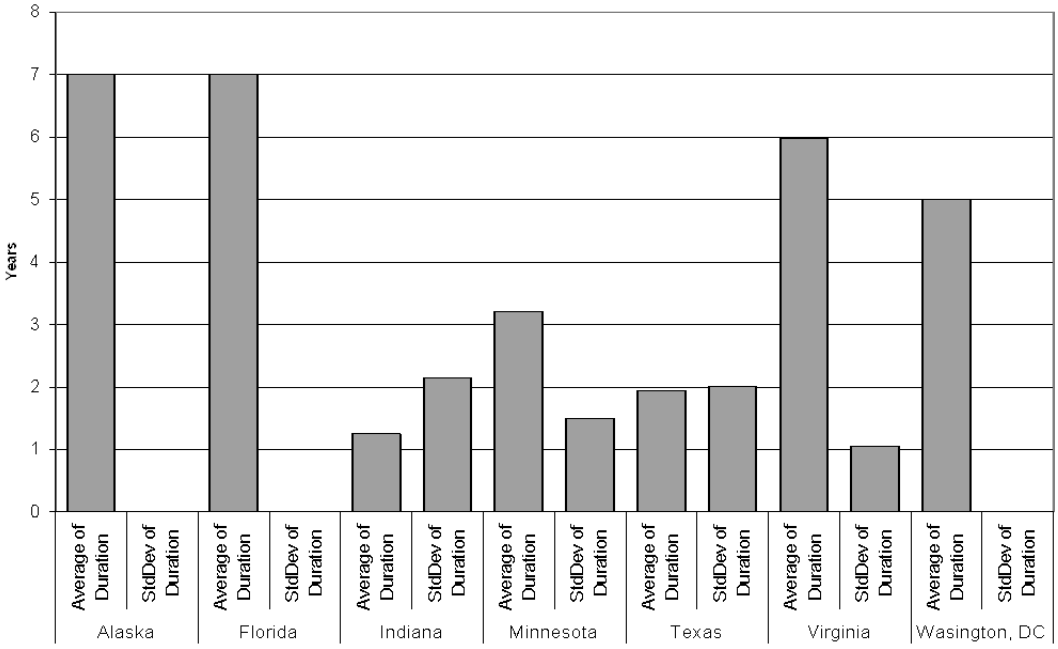


Figure 4.3. Average Contract Duration (in Years) by U.S. State

Regarding the length of the outsourced road sections, Figure 4.4 shows that PBCs had an average length of over 1,000 lane-miles, and a standard deviation of over 3,000 lane-miles, whereas the remaining contracting methods had much shorter lengths. This is likely due to the fact that long road segments (with several work activities in each

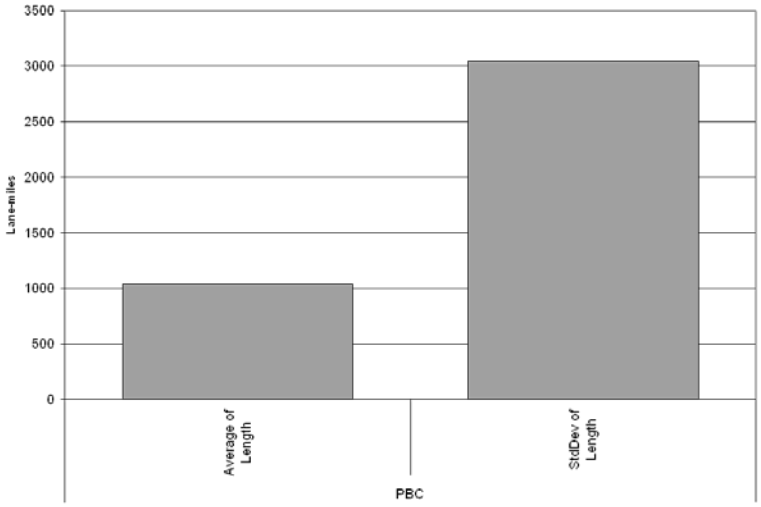


Figure 4.4. Average Contract Length (in Lane-Miles) by Contract Type

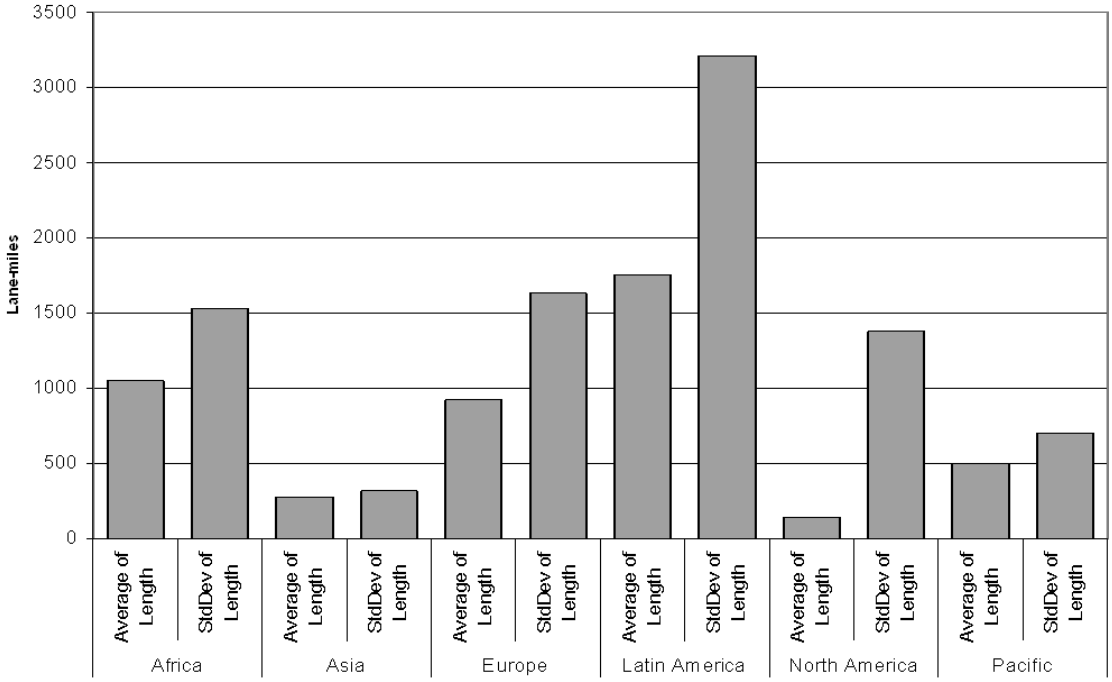


Figure 4.5. Average Contract Length (Lane-Miles) by Region

From Figure 4.5, it can be observed that contracts in Latin America had the greatest average length (1,750 lane-miles) with a very large standard deviation (3,250 lane-miles approximately). Africa and Europe had similar average length values (1,000 lane miles) with standard deviations (approximately 1,600 lane-miles). North America had the smallest average length (150 lane-miles approximately) but very large standard deviation (over 1,300 lane-miles). Figure 4.6 shows that, apart from Florida (where information from only one contract was available), Texas had the highest average length (240 lane-miles).

Figure 4.7 shows that PBCs had the largest average time extension or prolongation (more than 2.5 years), followed by the Incentives/Disincentives projects (2.3 years), Warranties (1.6 years), Cost-Plus-Time projects (almost 1.5 years), Lane rentals (1.4 years), Design-Build-Operate-Maintain (0.8 years), and Traditional contracts (over 0.5 years).

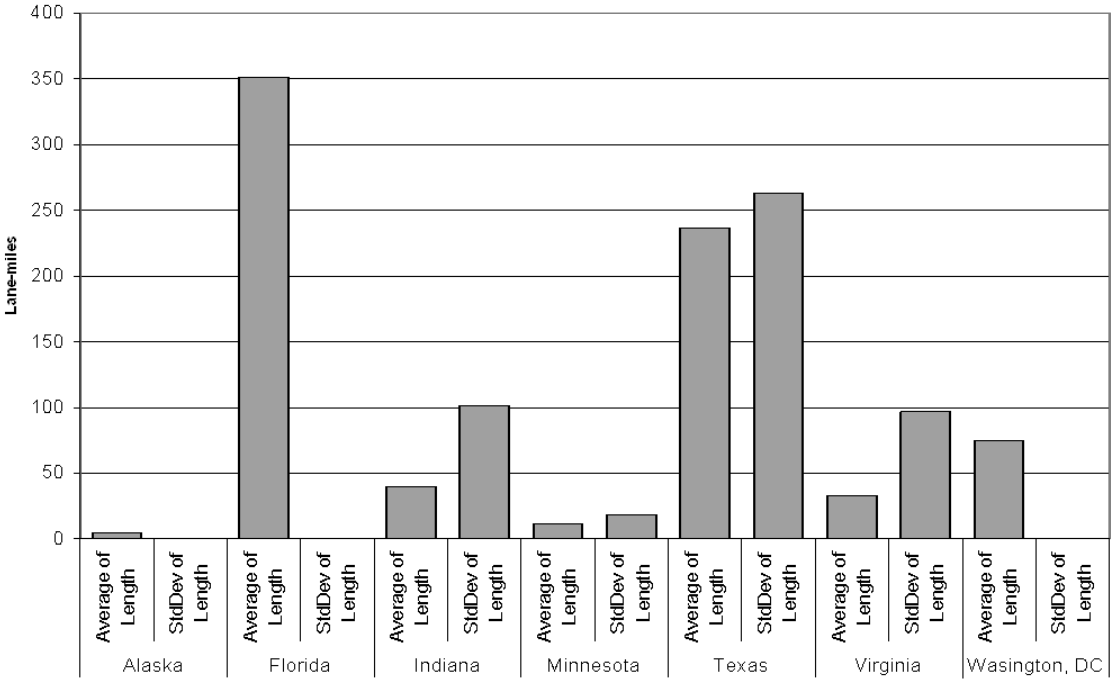


Figure 4.6. Average Contract Length (Lane-Miles) by U.S. State

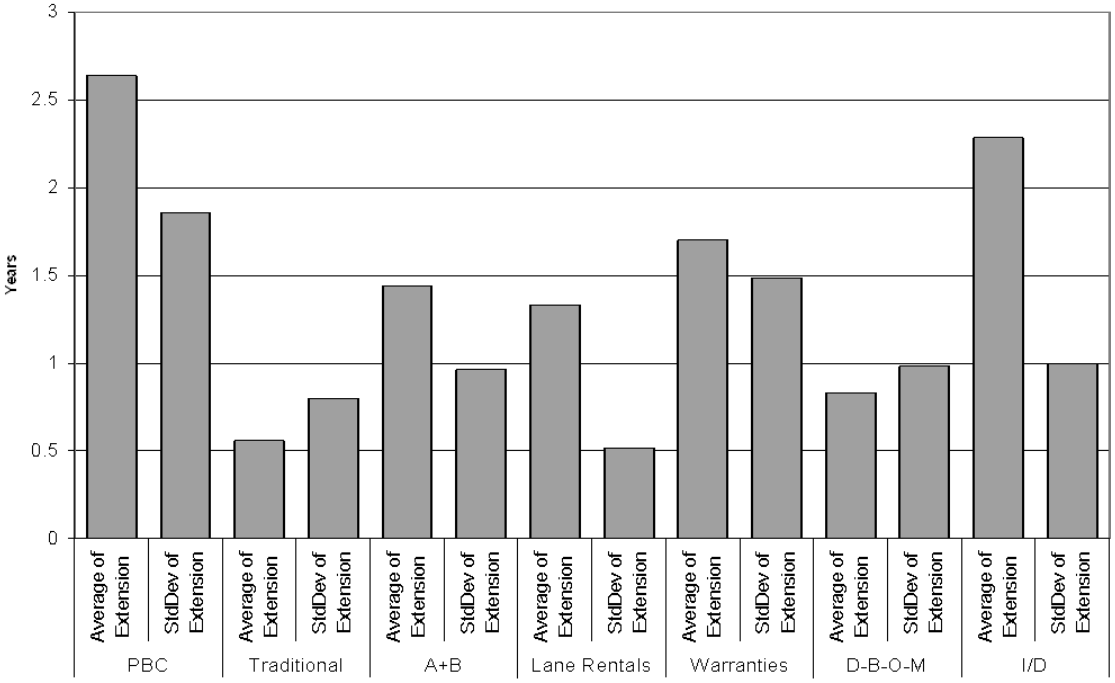


Figure 4.7. Average Contract Extension/Prolongation (in Years) by Contract Type

Figure 4.8 shows that compared with other regions, Europe, Africa, and the Pacific had higher prolongation periods, approximately 2.7 years; however, their standard deviations were varied: Africa (over 1.5 years), Europe (1.4 years), and the Pacific (2.5 years). The average in North America was over 1.3 years, and the standard deviation was approximately 1.5 years. Figure 4.9 shows that, apart from Florida and Washington DC (where only one contract in each case had an extension), the remaining U.S. states had generally similar average extensions. The highest was Virginia (over 1.5 years with a standard deviation of 1.5 years), followed by Minnesota (1.2 years with a standard deviation of 0.8 years) and Texas (about one year with a standard deviation of 0.9 years).

Regarding contract cost, Figure 4.10 shows the comparison of the average engineer's estimate (red dashed line) or in-house cost, average highest bid, and average final cost of the contracts. It can be observed that the average estimate was higher than both the average highest bid and average final cost, whereas the average in-house cost was lower than the average highest bid, but higher than the average final cost.

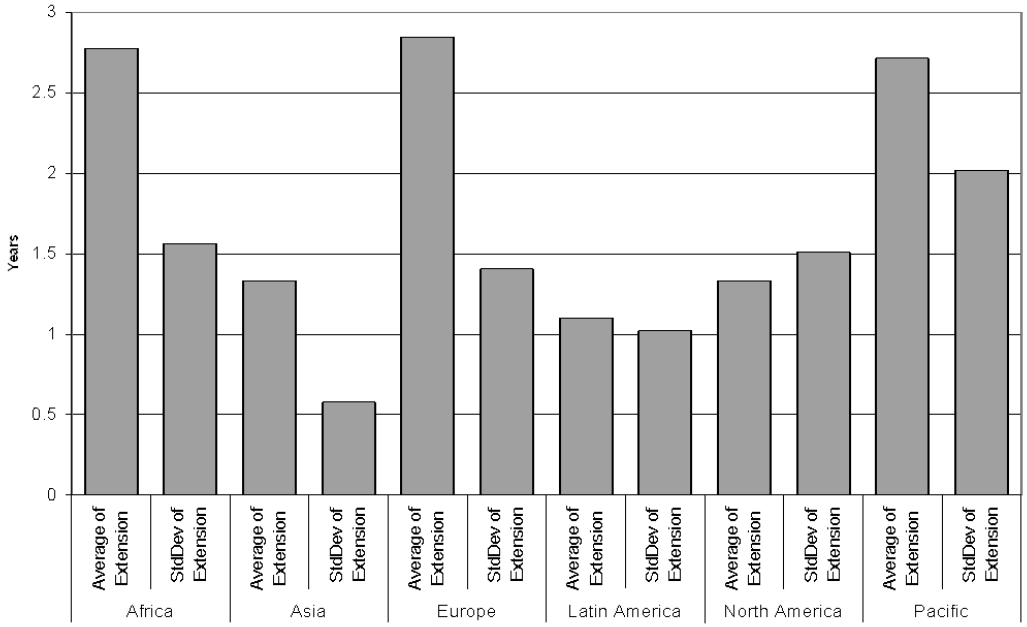


Figure 4.8. Average Contract Extension/Prolongation (in Years) by Region

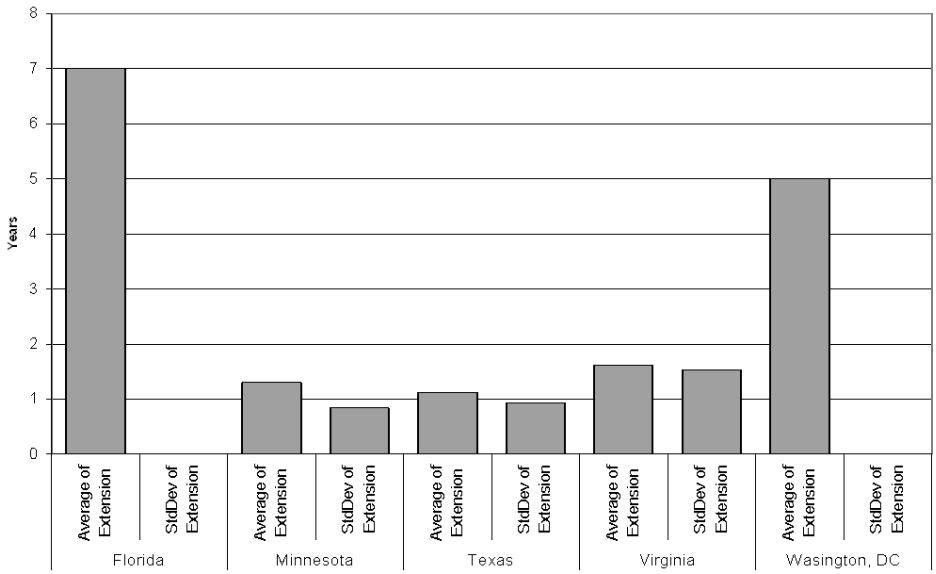


Figure 4.9. Average Contract Extension/Prolongation (in Years) by U.S. State

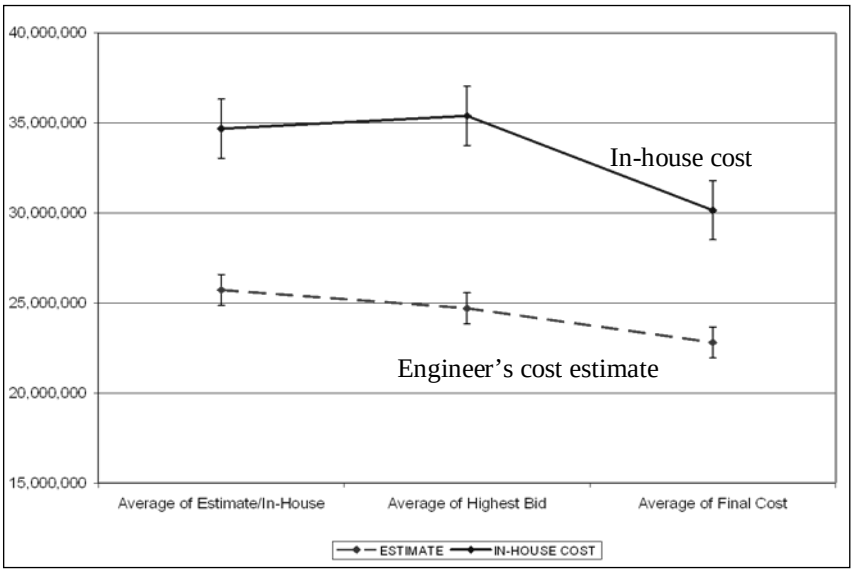


Figure 4.10. Contract Average Estimate, In-house Cost, Highest Bid, and Final Cost

From Figures 4.11 and 4.12, it can be observed that for DBOMs and PBCs, the engineer's estimate was higher than the highest bid, which was also higher than the contract's final cost. Also, for PBCs, the in-house cost was slightly lower than the highest bid, but much higher than the final cost. Interestingly, for Warranties, I/D, and

Traditional contracts, there was not much variance between the average in-house cost, highest bid, and final cost, indicating that all three amounts were very close; the conclusion was similar for the Lane Rentals, Warranties, and Traditional contracts' average estimates, highest bid amounts, and final cost. For the A+B and I/D projects, the average estimate amount was lower than the highest bid, but slightly higher than the final cost amount.

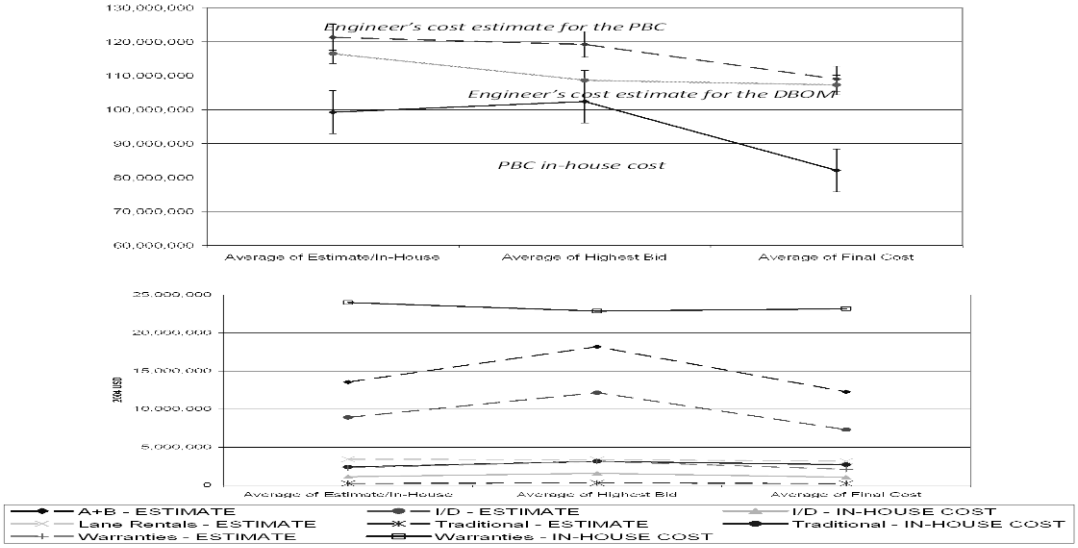


Figure 4.11. Average Estimate, Highest Bid, In-house & Final Cost ($), Part I

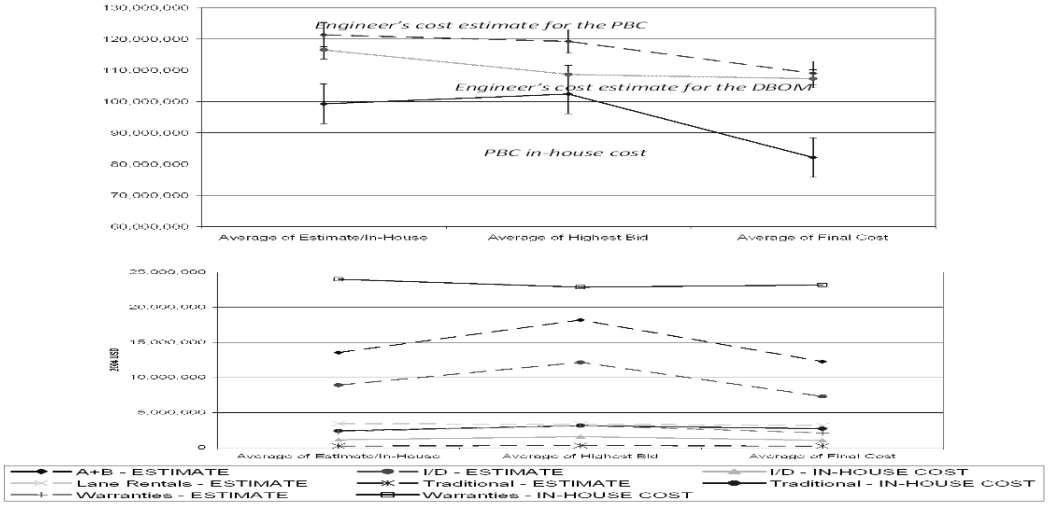


Figure 4.12. Average Estimate, Highest Bid, In-house & Final Cost ($), Part II

In Figure 4.13 it can be observed that for the European, South American, and Pacific contracts, the average in-house cost was slightly higher than the average highest bid, which in turn was significantly higher than the average final cost of the contract.

For the contracts originating from Africa, North America, and Asia, the three average values (in-house cost, highest bid, and final cost) were almost identical. Also, for the North America contracts, the averages of the engineer's estimate amount, the highest bid, and the final cost were also at the same level. Hence, there was no an evident trend in the relationship of the costs for these cases.

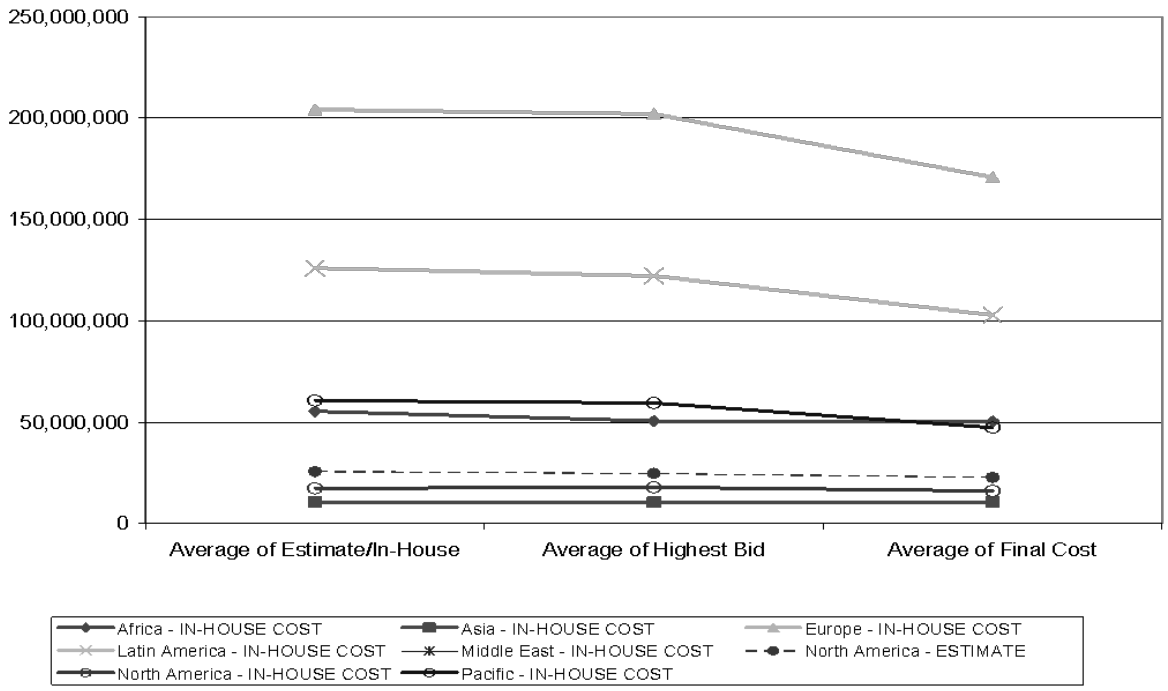


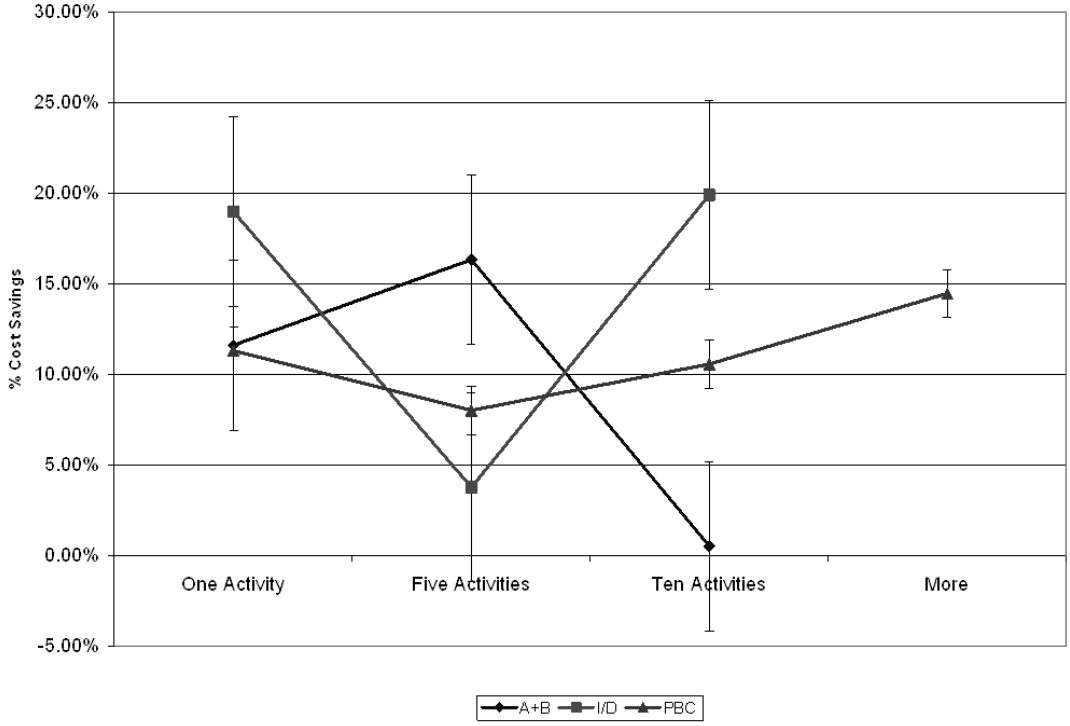
Figure 4.13. Average Estimate, Highest Bid, In-house and Final Cost ($) by Region

In Alaska, there was only one contract (PBC), and the in-house cost was higher than the highest bid submitted, which in turn was almost identical to the final cost. In Florida, the situation was very similar to Alaska, except that instead of the in-house cost, the engineer's estimate was compared to the highest bid and final cost.

In Indiana, the average estimate was lower than the average highest bid, and was almost as high as the average final cost. However, the average in-house cost was much higher than the average highest bid, and also lower than the average final cost. In Minnesota and Virginia, the average engineer's estimate was slightly lower than the average highest bid and slightly higher than the average final cost.

In Texas and Washington DC, the average engineer's estimate, the average highest bid, and the average final cost were almost identical. Similarly, the average in-house cost, the average highest bid, and the average final cost were almost identical in Virginia. Finally, in Texas, the average in-house cost was almost as high as the average final cost, but the highest bid was much higher than both of them. However, in this last case, the standard error was very large (as shown in Figure 4.14).

In Figure 4.14 the average cost savings (in percentage) for the number of activities incorporated in a project by contract type are presented. Interestingly, except for the Lane Rentals, where there was a negative linear relationship between the cost savings and the number of activities included in the contract, for all other contracting methods the relationship was not linear. However, for PBCs (and partially for Warranties) it can be observed that, for a large number of activities, higher cost savings were more likely. For the remaining contracting methods, it was very difficult to draw conclusions.



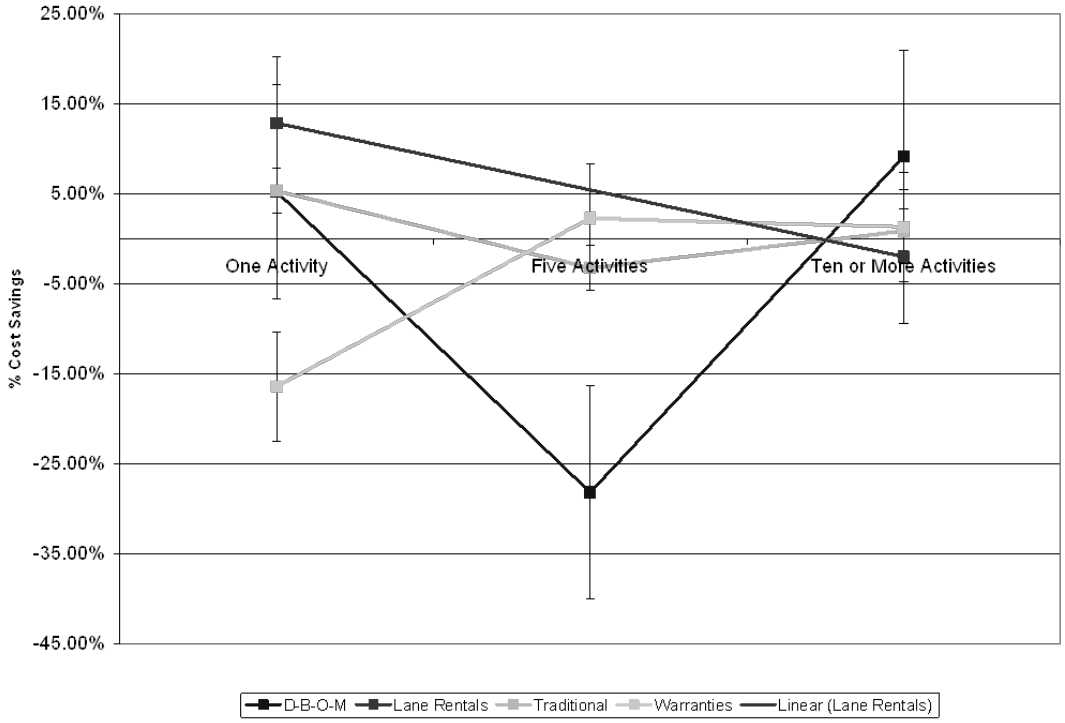


Figure 4.14. Percent Cost Savings for Number of Activities by Contract Type

In Figure 4.15 the average cost savings (in percentage) associated with the inclusion (or exclusion) of specific maintenance and rehabilitation activities is presented. It can be observed that the inclusion of the following activities in a contract are associated with higher cost savings: culvert/ditches/gutters/drainage repair/ maintenance/replacement, emergency facilities maintenance/response, illumination repair/maintenance, shoulder repair/maintenance, traffic signs and signals, and all activities. Higher cost savings, on the other hand, was found to be associated with the exclusion of the following activities in a contract: crack/pothole sealing/repair, landscape repair/ maintenance, and litter removal.

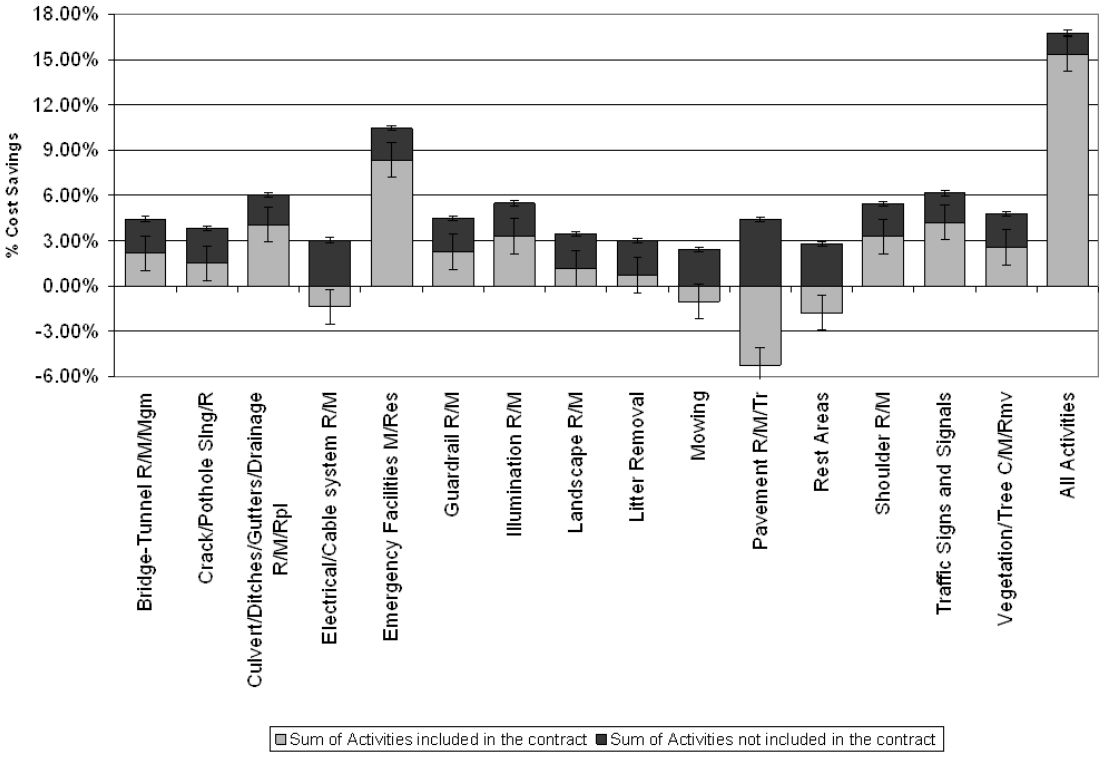


Figure 4.15 Cost Savings by Specific Maintenance and Rehabilitation Activities

Also, inclusion of the following activities were more likely to be associated with cost loss, and also associated with cost savings if they were excluded from the contract: electrical/cable system repair/maintenance, mowing, pavement repair/ maintenance/treatment, and rest areas.

In Figure 4.16, the apparent relationship between the cost savings and the length (lane-miles) of the outsourced road sections is presented for each contract type. The straight lines are linear trendlines indicating the direction of the relationship. It can be observed that there was a general increasing trend between the cost savings and length: the higher the length, the higher the cost savings. However, in all cases, the variance was very high. For A+B and Lane Rentals projects, there seems to be an inverse relationship: the greater the lane-miles included in the contract, the lower the cost savings. However, the starting and ending points of the A+B trendline in the figure are both in the cost savings area, whereas, for Lane Rentals, the ending point is in the loss area. For DBOM projects an inverse relationship (the greater the length, the lower the cost savings) seems to be evident; however the slope is gentle.

For PBCs, Warranty, and Traditional contracts, the relationship between the length and the cost savings seems to be positive, albeit with a trendline slope that is not steep. However, for PBCs, the trendline starting point is above 10% of the cost savings and increases as the contract length increases; whereas for the Warranty and Traditional projects, the starting point is very close to 0% cost savings.

Finally, for I/D contracts, there seems to be a direct relationship between the percent cost savings and the length: the greater the contract length, the higher the cost savings. Also, the slope is steep and both the starting and ending points of the trendline are in the cost savings area.

In Figure 4.17, the relationship between the percent cost savings and the contract duration (years), along with the related trendline (straight line) are presented. The figure suggests that there is a direct relationship between the two: cost savings increases as the duration increases. However, due to the large variation of the data points, it is not possible to draw conclusions by simply observing the data presented in the figure.

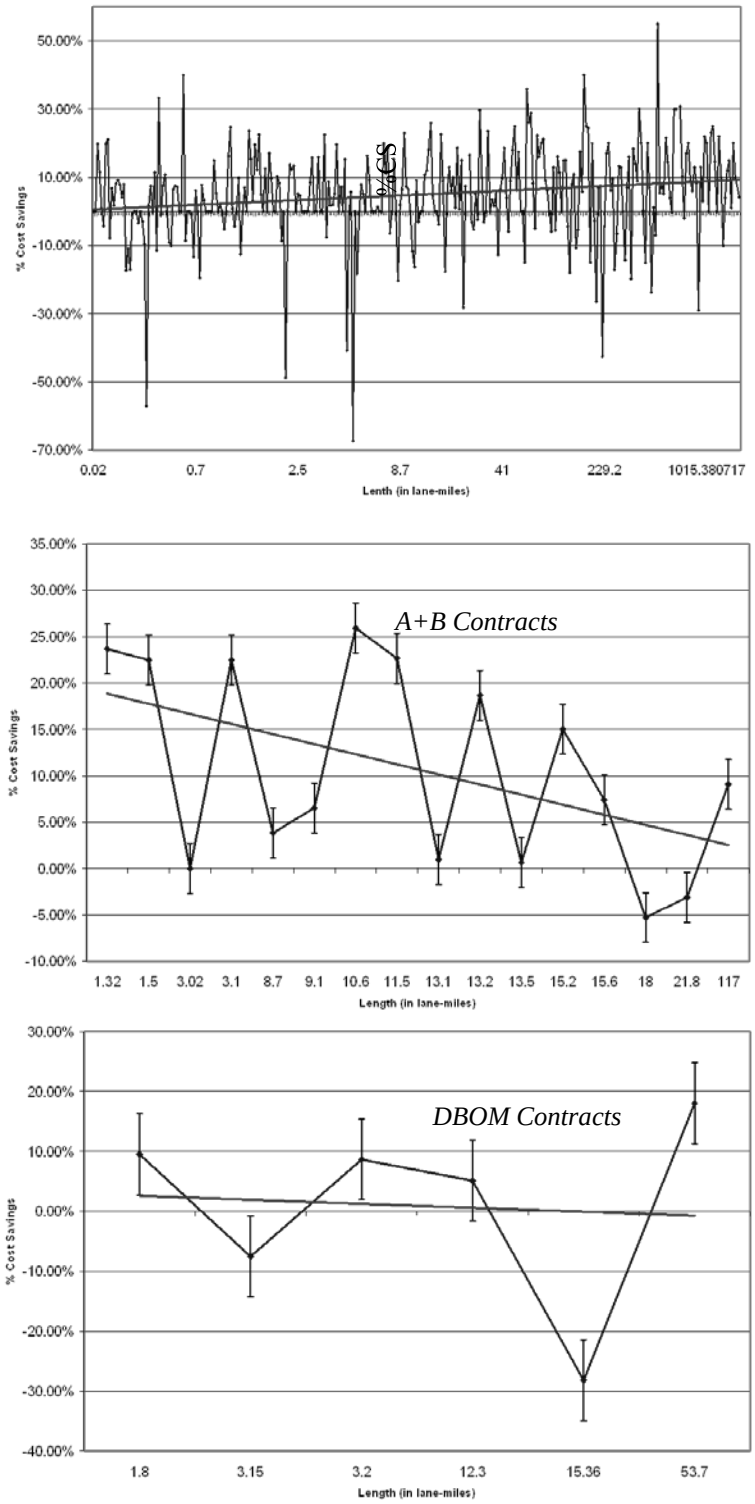


Figure 4.16A Cost savings and length by contract type

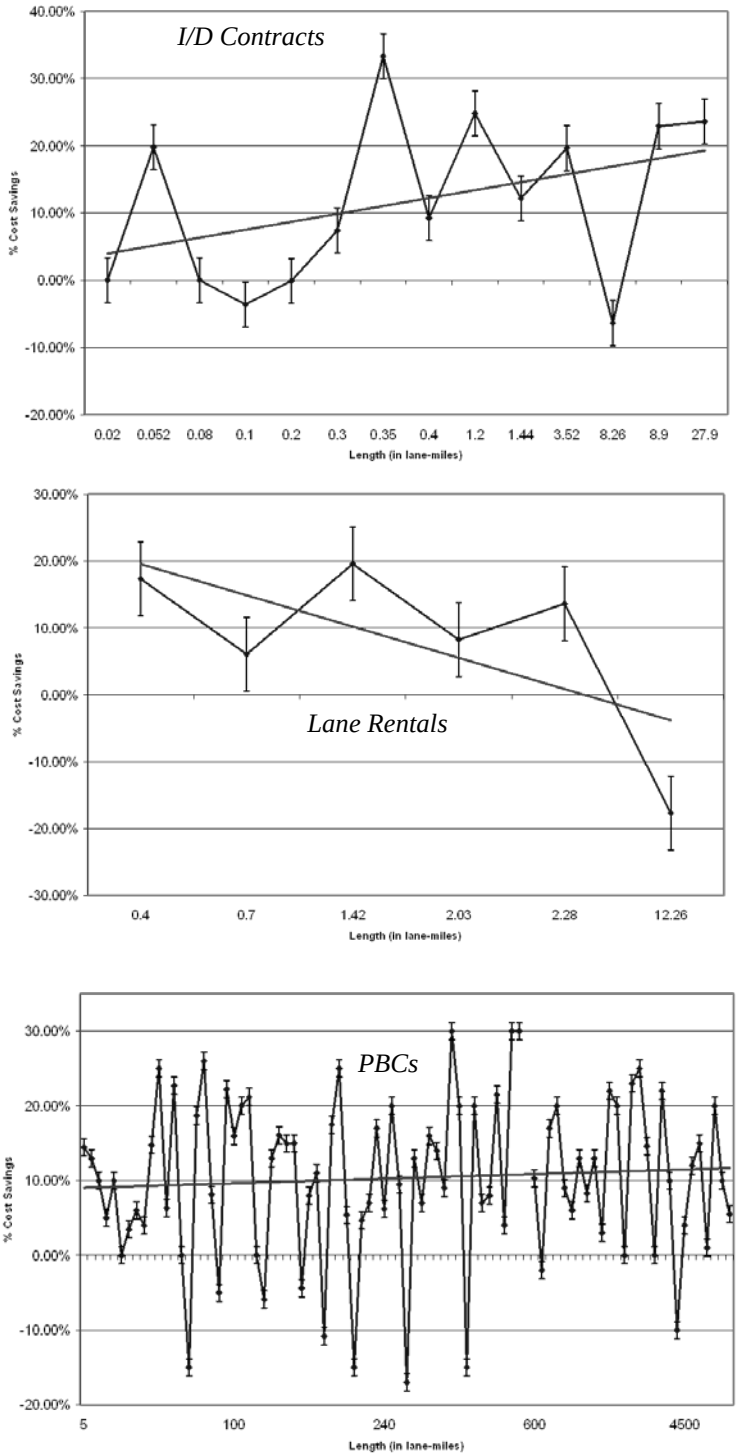


Figure 4.16B Cost savings and length by contract type

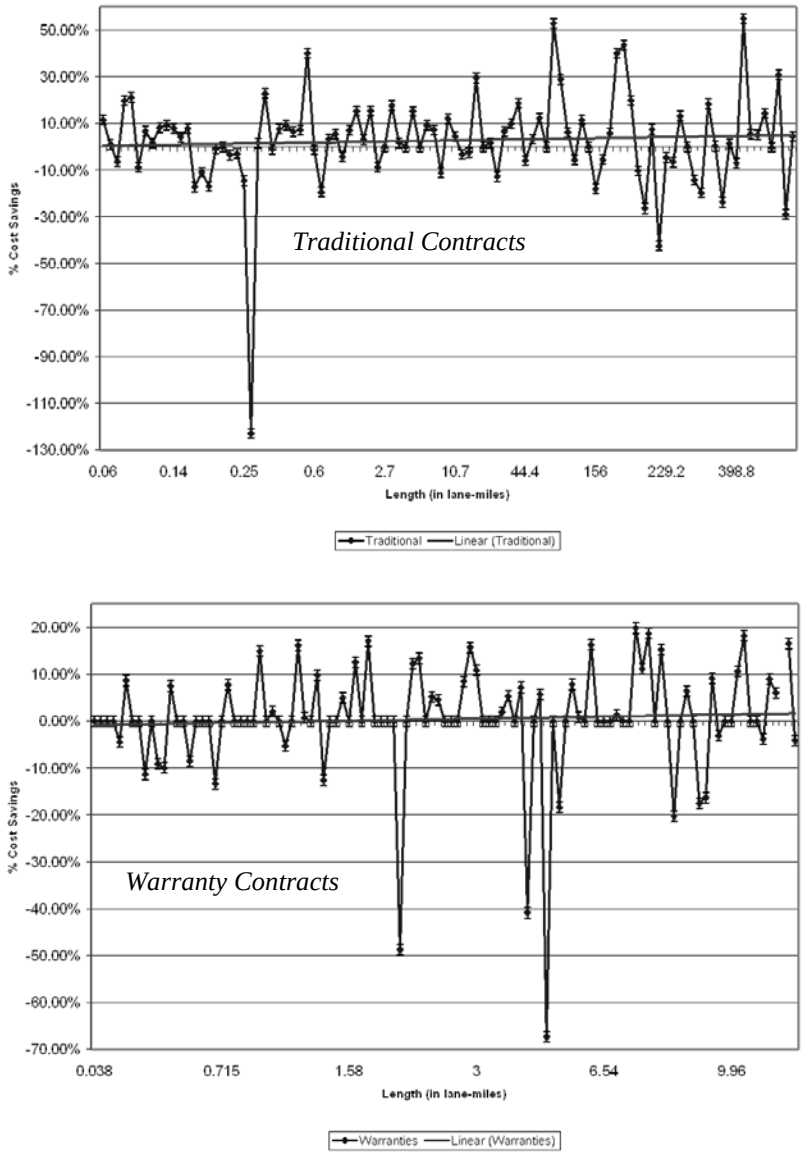


Figure 4.16C. Cost Savings and Length by Contract Type

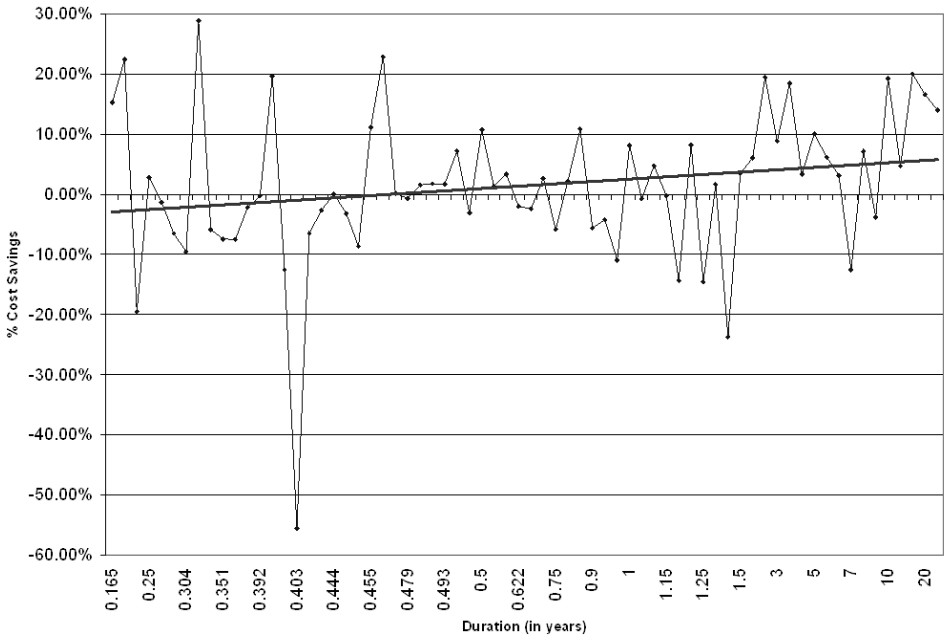


Figure 4.17. Cost Savings and Contract Duration

Figure 4.18A and B illustrate the cost savings and contract duration relationships for each contract type. For A+B, Lane Rentals, DBOM, and I/D projects there are inadequate observations to identify a trend, thus no tentative conclusions should be made at this stage of the analysis.

Also, for Traditional and Warranty projects, the related trendlines presented in the figure do not indicate an apparent relationship between the contract duration and cost savings. However, for PBCs, it can be observed that there seems to be a direct relationship between duration and cost savings: the higher the contract duration, the higher the cost savings.

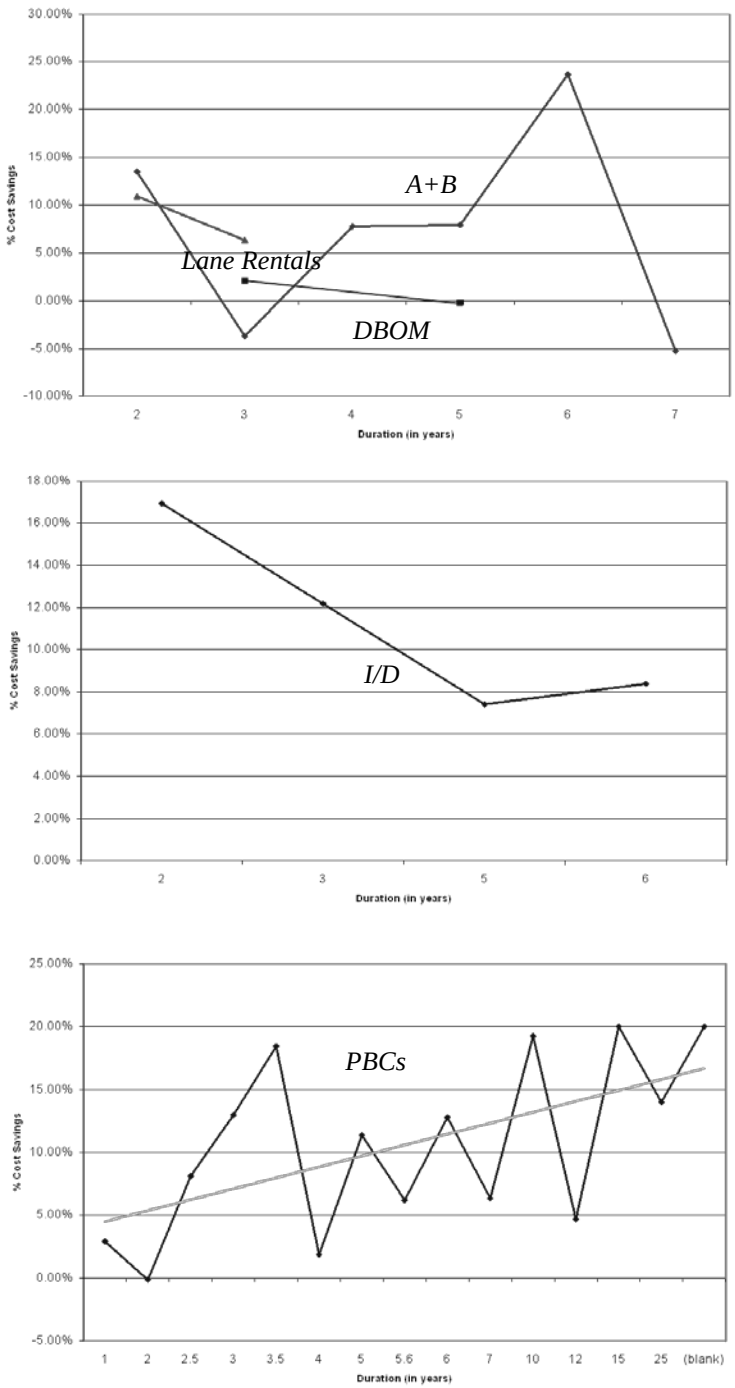
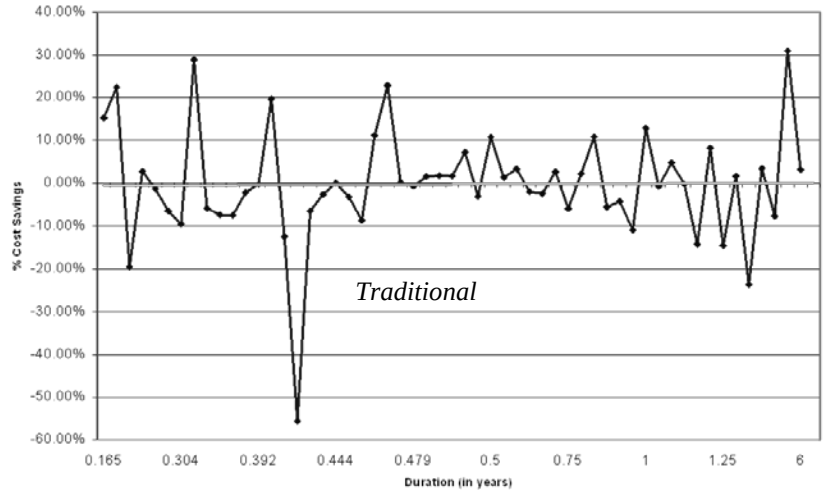


Figure 4.18A Cost savings and contract's duration by contract type



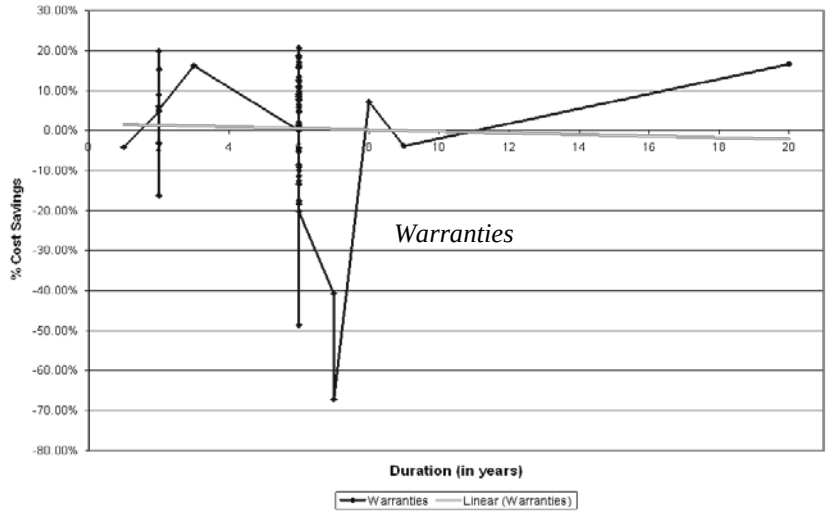


Figure 4.18B. Cost Savings and Contract's Duration by Contract Type

Figure 4.19 presents the relationship of the extension/prolongation (measured in years) of the contract and the cost savings. It can be observed that for an extension/prolongation up to six years, the cost savings increases (indicated by the trendline without the outliers). After that point, though, the cost savings significantly decrease (hence the inverse relationship indicated by the trendline where the outliers are included).

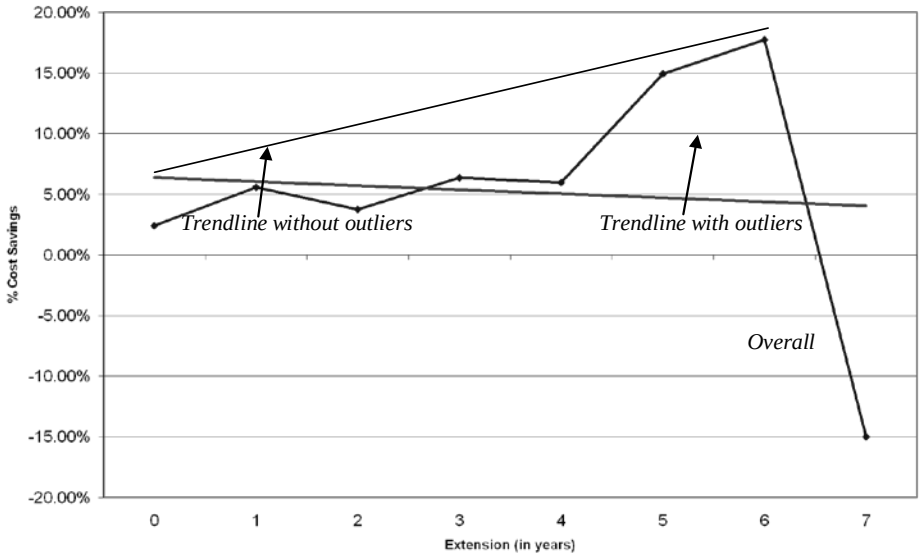


Figure 4.19. Cost Savings and Contract Extension/Prolongation (Years)

In Figure 4.20, it can be observed that there is a relationship between contract extension/prolongation and cost savings by contract type. Although there is no apparent trend in most of the contracting methods, in PBCs, the relationship of the extension/prolongation and cost savings appears to be direct (the cost savings increase as the extension/prolongation increases) until the extension/prolongation reaches the sixth year; after that point, the cost savings significantly decreases.

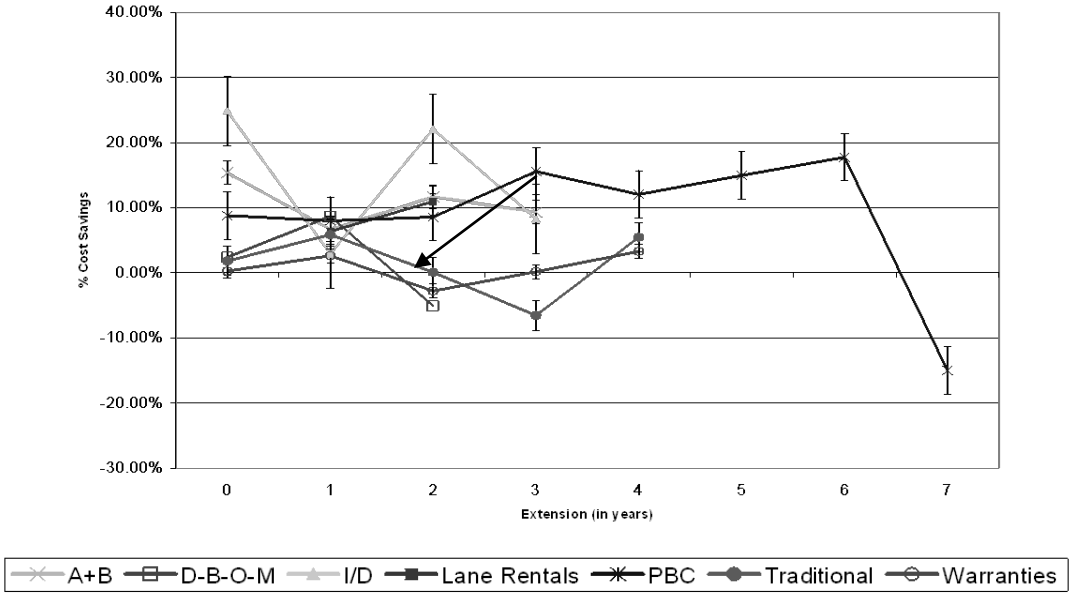


Figure 4.20. Cost Savings and Extension/Prolongation by Contract Type

In Figure 4.21, it is shown that for A+B and Warranty contracts, local road projects (non-interstate road projects) appear to be more likely to have higher cost savings. However, interstate projects are also likely to have cost savings. For DBOM contracts, local road projects seem to be more likely to have cost savings, whereas interstate projects are more likely to suffer loss. For Lane Rentals and I/D contracts, interstate projects are seen to be more likely to have cost savings (no local road projects were available, though, to compare). Finally, for performance-based and traditional contracts, the cost savings seem to be independent of the road class.

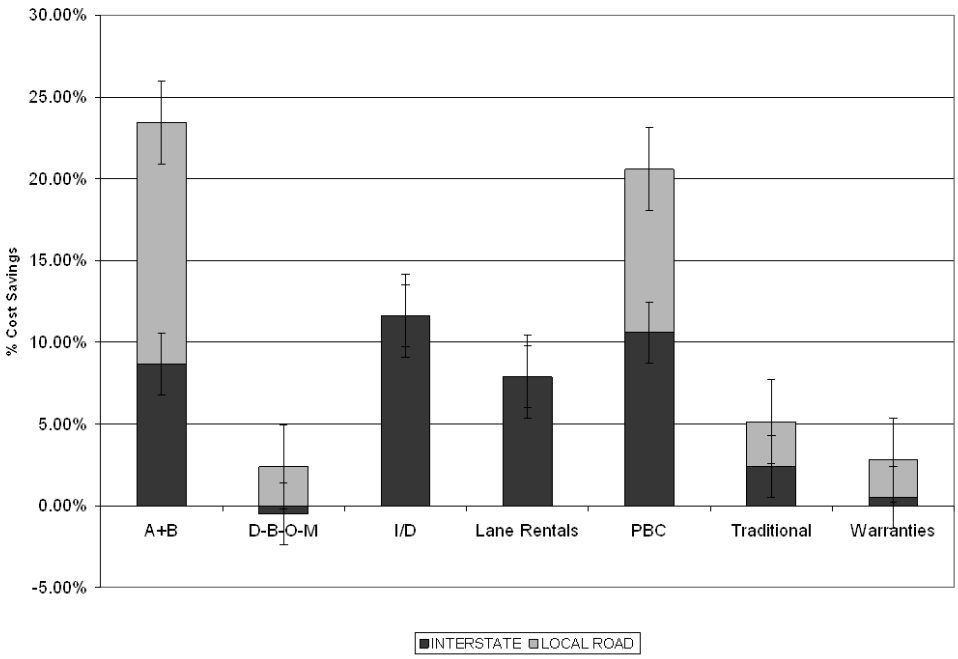


Figure 4.21. Cost Savings for Roadway Projects by Road Class and Contract Type

Figure 4.22 illustrates the competition level and cost savings relationship (along with the standard deviations). The trendline (straight line) suggests that the higher the number of submitted bids (the stronger the competition), the higher the cost savings.

Figure 4.23 presents the relationship of the bid range (difference between the lowest and highest bid, in 2006 $) and the related cost savings. The trendline (straight line) seems to suggest that there is a somewhat direct relationship between the cost savings and the bid

range: the larger the bid range, the greater the cost savings. This relationship is consistent with the number of bids and the cost savings relationship discussed earlier.

From the related trendlines (straight lines) in Figure 4.24, it can be observed that for A+B, Lane Rentals, I/D, PBCs, and Warranty projects, there appears to be a direct relationship between the bid range and the cost savings: the greater the bid range, the greater the cost savings. On the other hand, for DBOM and Traditional contracts, there is an inverse relationship: the greater the bid range, the lower the cost savings.

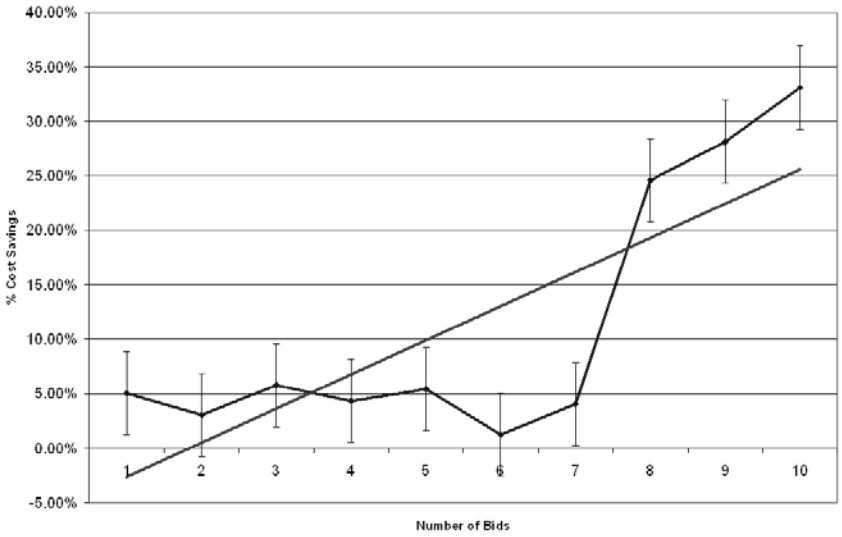


Figure 4.22. Cost Savings and Number of Submitted Bids with Trendline

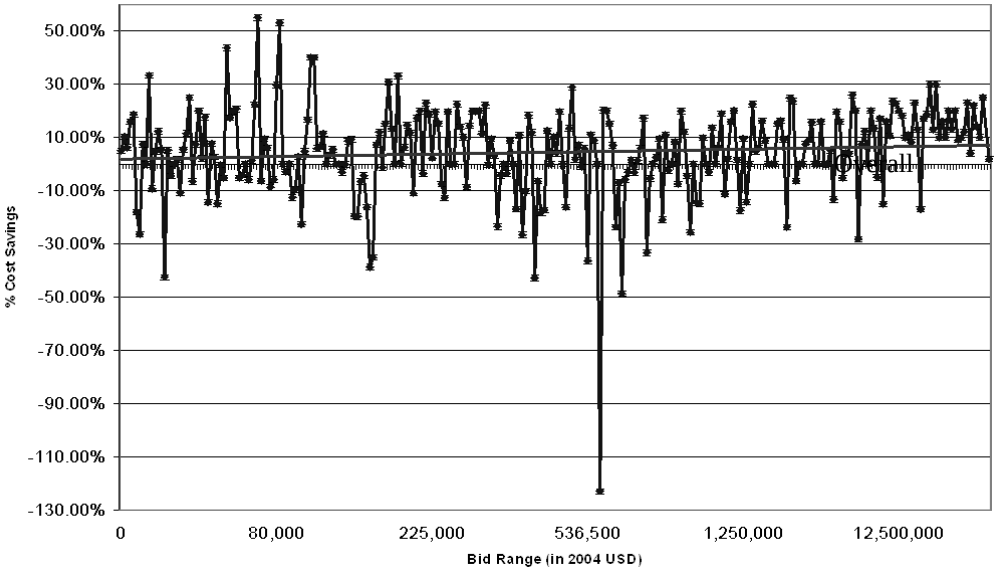


Figure 4.23 Cost Savings and Bid Range with Trendline

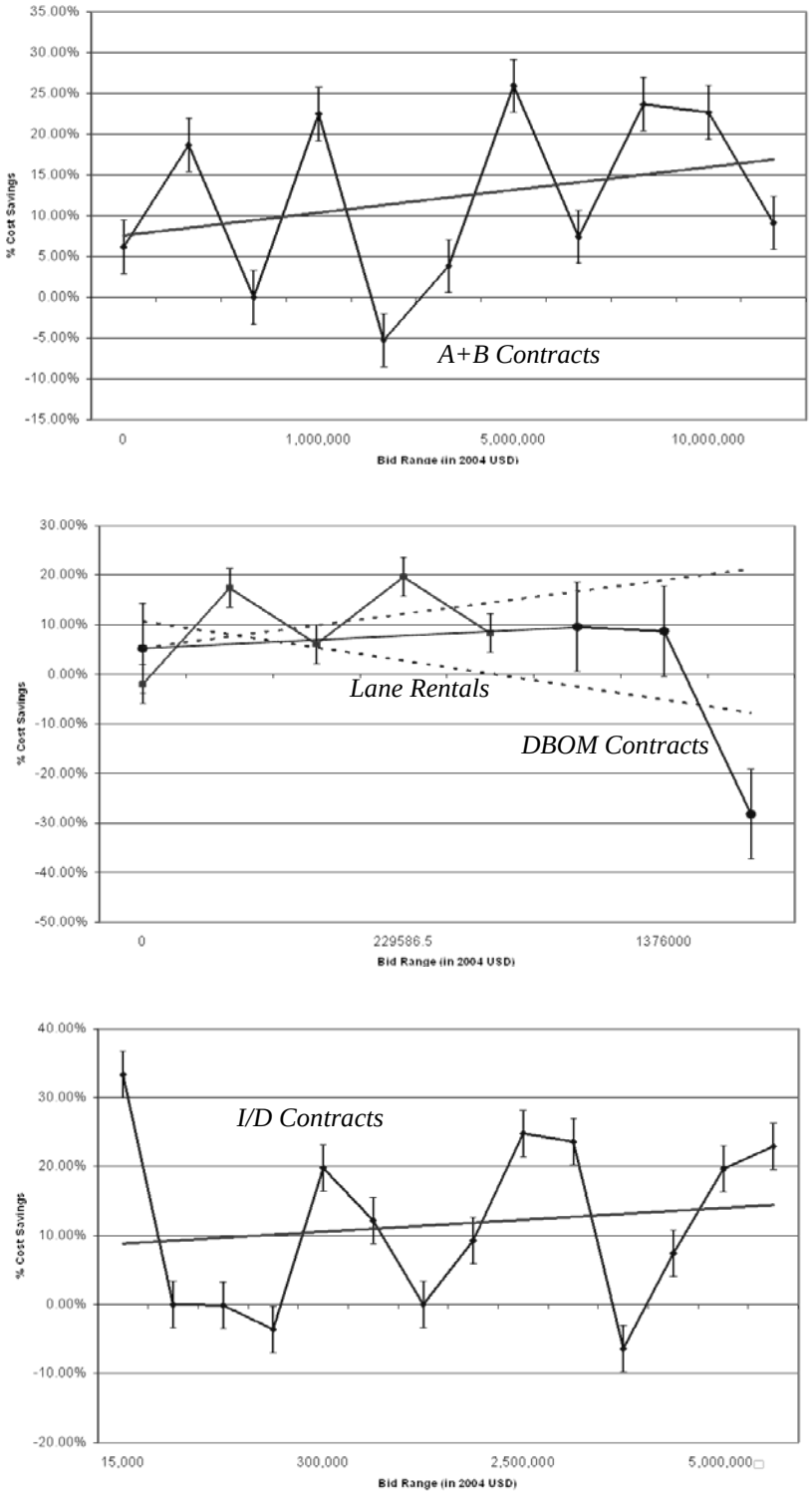


Figure 4.24A. Cost Savings and Bid Range by Contract Type

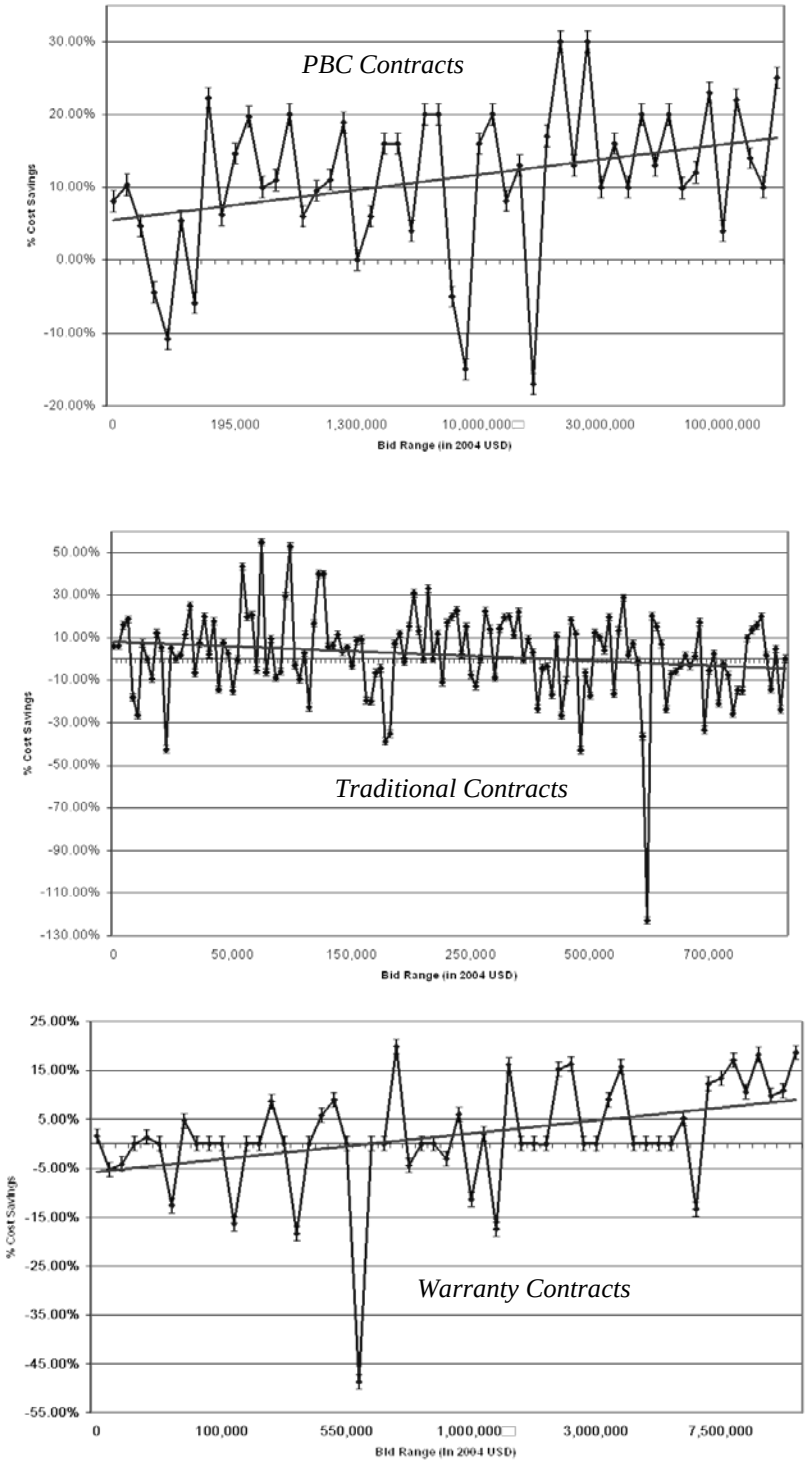


Figure 4.24B. Cost Savings and Bid Range by Contract Type

4.4 Econometric Modeling - Estimating Cost Savings for Each Contracting Approach

4.4.1 Prelude

In the context of this study, an important issue is the extent to which a given evaluation criterion such as cost savings is realized when a specific contracting approach is used to deliver a given project. This is a key part of the contracting approach evaluation and selection framework presented in this report. Using this framework, the most appropriate decision can be made as regards the best contracting approach on the basis of the physical project size (length), the expected contract duration, etc.

It is important to highlight the definition of cost savings as used in this study. In many past reports, road agencies have reported "cost savings" as the difference between the engineer's cost estimate and the awarded bid amount (as in Texas) or the engineer's cost estimate and the final contract cost (as in Florida). In both cases, the intent of the cost savings determination was in a different context, as their output was intended to be a reflection of the closeness of the engineer's estimate to the actual bid amount of final cost, rather than the cost savings of a specific contract or contracting approach relative to another. For the purposes of this report, "cost savings" is defined as the difference between the cost of the project delivery carried out in-house and that carried out using a contracting approach. The details of this definition are provided in the next section.

A statistical/econometric analysis was conducted on the collected data. As discussed earlier, data on 570 contracts were collected. The cost savings (normalized, measured in percentages) were modeled as the evaluation criterion. When a road agency considers implementing a road project, a design cost is first estimated. Next, the agency engineers determine a cost estimate (usually, the engineer's cost estimate should be close to the design cost within a range (e.g. ±10%). This engineer's cost estimate is used as the basis for comparison during the contractor bid evaluation and selection procedure. The best/awarded bid is the cost that the agency is expected to pay the contractor upon project completion; however, in most cases there are cost overruns or underruns. The magnitude of the overruns varies with the contract's size and activities. The likelihood and magnitude of a PPP contract experiencing cost savings or loss relative to the base case was investigated by estimating binary probit models and linear regression models, respectively.

For the cost savings analysis, the influence of the following potential key elements that determine cost savings were investigated: (a) the contract size (final cost of the contract), (b) the contract duration, (c) the contract extension/prolongation, and (d) the physical size of the contract (length).

For the data collation and descriptive statistics, Excel (MS Office XP) and SAS (v. 9.1) were used; and for the econometric modeling, Limdep (v. 7.1), NLOGIT (v. 3.0), and SAS (v. 9.1) were used.

4.4.2 Methodology

The cost savings was taken as the amount saved (or lost) for a given contract due to the use of a PPP contracting approach relative to a base contracting approach (e.g., traditional or in-house). This can be expressed as a percentage change of the application of the new PPP contracting approach, over the base approach. For example, assuming that the cost of a portfolio of maintenance activities carried out in-house is $4 million, whereas an identical portfolio is carried out using PBC is $3 million, the cost savings due to PBC is $4 million – $3 million = $1 million, and the percent cost savings is:

$\frac{\$4 million - \$3 million}{\$4 million} \times 100 = 25\%$. The use of the percentage cost savings is preferred, because bias in the estimates due to project cost, is avoided. Hence, the formula used in this study for the cost savings is as follows:

$$\%CS = \frac{CB - CA}{CB} \times 100$$

where, %CS is the percent cost savings, CB is the cost of the contract with the base contracting approach, and CA is the cost of an identical contract with the PPP contracting approach.

First, the possibility of cost savings for a given project was analyzed using a binary probit model. Then, a linear regression model was applied to investigate the expected magnitude of cost saved or lost. In each case, the selection of the best model was based on intuitive arguments, the number of observations, and goodness-of-fit measures.

For these modeling techniques, contract data from the U.S. and other countries were used. To account for specific characteristics that may cause the variables to differ between contracts in the U.S. and those of other countries, likelihood ratio tests were carried out.

4.4.3 Transferability Check using Likelihood Ratio Tests

The likelihood ratio test investigates whether a model's estimated parameters are spatially or temporally transferable (Washington et al., 2003). Spatial transferability ensures that the estimated parameter coefficients are stable over space, which in this report, would mean that estimated parameters are stable in both the U.S. and in international PPP contracts. The likelihood ratio test is (Washington et al., 2003):

$$X^2 = -2 \times [LL(\beta_T) - LL(\beta_a) - LL(\beta_b)] \tag{4.2}$$

where, α and b the two regions (U.S. and International PPP contracts, respectively) between which the transferability of parameters is tested, $LL(\beta_T)$ the log likelihood at convergence of the model estimated with the data from both regions, $LL(\beta_\alpha)$ the log likelihood of convergence of the model using region α data (U.S. PPP contracts), and $LL(\beta_b)$ the log likelihood of convergence of the model using region b data (International PPP contracts).

This X^2 test statistic is χ^2 distributed with degrees of freedom equal to the summation of the number of estimated parameters in all regional models (α - U.S. PPP contracts and b - International PPP contracts) minus the number of estimated parameters in the full model (both U.S. and International PPP contracts). The resulting X^2 statistic provides the probability that the models have different parameters.

For all PPP approaches, the conducted likelihood ratio tests showed that at a 0.90 level of confidence, there is no evidence to reject the null hypothesis, H_0, of equality across the two data segments.

4.4.4 Binary Probit Model

Binary models are models that consider two discrete outcomes. An estimable model of discrete outcomes is (Washington et al., 2003):

$$P_n(i) = P(\beta_i X_n - \beta_I X_n \geq \varepsilon_{In} - \varepsilon_{in}) \forall I \neq i, \qquad (4.4)$$

where, I is all the possible outcomes for observations n, β_i a vector of estimable parameters for discrete outcome i, X_n a vector of the observable characteristics that determine discrete outcomes for observation n, $P_n(i)$ the probability of observation n having discrete outcome i ($i \in I$), and ε the disturbance terms. Probit models arise when the ε in Equation 4.4 is assumed to be normally distributed, and in the binary case (two outcomes, notated 0 or 1), Equation 4.4 becomes:

$$P_n(0) = P(\beta_0 X_{0n} - \beta_1 X_{1n} \geq \varepsilon_{1n} - \varepsilon_{0n}), \qquad (4.5)$$

where the probability of outcome 0 occurring for observation n is estimated, with ε_{0n} and ε_{1n} being normally distributed with mean = 0, variances σ^2_0 and σ^2_1, respectively, and covariance σ_{01}. A property of the normally distributed variates is that the addition or subtraction of two normally distributed variates produces a normally distributed variate. In such a case $\varepsilon_{1n} - \varepsilon_{0n}$ is normally distributed with mean = 0 and variance $\sigma^2_0 + \sigma^2_1 - \sigma^2_{01}$. Thus the resulting cumulative normal function is (Washington et al., 2003):

$$P_n(0) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\beta_0 X_{0n} - \beta_1 X_{1n}}{\sigma}} e^{\left(-\frac{1}{2}w^2\right)} dw, \qquad (4.6)$$

where $\sigma = (\sigma^2_0 + \sigma^2_1 - \sigma^2_{01})^{1/2}$. w is an operative that goes from $-\infty$ to the differences in β, and is used to generate the probabilities.

If Φ (.) is the standardized cumulative normal distribution, then Equation 4.6 becomes (Washington et al., 2003):

$$P_n(0) = \Phi\left(\frac{\beta_0 X_{0n} - \beta_1 X_{1n}}{\sigma}\right). \qquad (4.7)$$

The term $1/\sigma$ is a scaling of the function that determines the discrete outcome and can be set to any positive value, although σ=1 is typically used (Washington et al., 2003).

The parameter vector β, can be estimated using standard maximum likelihood methods (Washington et al., 2003):

$$L = \prod_{n=1}^{N} \prod_{i=1}^{I} P(i)^{\delta_{in}}, \qquad (4.8)$$

where, L the likelihood function, N the total number of observations, and δ_{in} defined to be equal to one if the observed discrete outcome for observation n is i, and zero otherwise. In the binary case (i = 0 or 1, the log likelihood (Eqn 4.8) is (Washington et al., 2003):

$$LL = \sum_{n=1}^{N}\left[\delta_{0n} LN\Phi\left(\frac{\beta_0 X_{0n} - \beta_1 X_{1n}}{\sigma}\right) + (1-\delta_{0n}) LN\Phi\left(\frac{\beta_0 X_{0n} - \beta_1 X_{1n}}{\sigma}\right)\right]. \qquad (4.9)$$

4.4.5 Linear Regression Model

The assumptions of the linear regression are as follows (Washington et al., 2003):

(a) The dependent variable should be continuous taking any value within a range of values.

(b) The linear-in-parameters relationship between the dependent and the independent variables. The linear regression model is given by:

$$Y_i = \beta_0 + \beta_1 \times \mathrm{X}_{1i} + \varepsilon_i$$

where, Y_i the dependent variable which is a function of a constant term β_0 (the point where the regression line crosses the Y axis) and a constant β_1 times the value X_1 of independent variable X for observation i (where the observation i = 1, 2, 3, …, n), plus a disturbance term ε. Because the scales of both the dependent and independent variables can be transformed, a suitable linear relationship can often be found; hence, this requirement is not that restrictive.

(c) The observations should be independently and randomly sampled from the population. Independence requires that the probability of an observation being selected is not affected by any other observations of the sample.

(d) The relationship among the variables should be uncertain. The disturbance term ε is the main difference between a straight line equation and linear regression. So, ε may contain omitted variables, measurement errors in the dependent variables, or random variation innate in the underlying data-generating process.

(e) Homoscedasticity of the disturbance terms. The variance of the disturbance terms, σ^2, should be independent of the independent variables across observations, and their expected values should be zero:

$E[\varepsilon_i] = 0$, and

$VAR[\varepsilon_i] = \sigma^2$.

The homoscedasticity assumption implies that the net effect of model uncertainty is random across observations and covariates.

(f) The disturbance terms should not be autocorrelated. Disturbances ε should be independent across observations:

$$COV[\varepsilon_i, \varepsilon_j] = 0 \quad \textbf{if} \quad i \neq j$$

A violation of the homoscedasticity assumption occurs when observations are repeated on individuals, so the unobserved heterogeneity portion of the ε is not different across repeated observations.

(g) Exogeneity of the regressors. The regressors and disturbance terms should not be correlated. Exogeneity implies that Y does not directly influence the value of an exogenous regressor:

$$COV[X_i, \varepsilon_j] = 0 \quad \textbf{for all i and j}.$$

(h) Disturbances should be approximately normally distributed. In order to make inferences about the model's parameters, the ε should be approximately normally distributed. In combination with the independence assumption, this property results in disturbance terms that are independently and identically distributed as normal:

$$\varepsilon_i \approx N(0, \sigma^2).$$

Ordinary Least Squares estimation is a commonly employed estimation method for linear regression. It represents a method for estimating regression model parameters using the sample data.

4.5 Results

4.5.1 Cost Savings Likelihood

For each contracting approach (i.e., traditional maintenance, traditional rehabilitation, design-bid-build, PBC, lane rentals, warranties, and A+B+I/D), the probability of having cost savings (or experiencing loss) was investigated by estimating binary probit models. Table 4.2 illustrates selected descriptive statistics by contracting approach type, whereas Table 4.3 presents the model results for all PPP approaches.

Table 4.2. Selected Descriptive Statistics by Contracting Approach

Traditional Contracts (Maintenance):	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	2.941	2.648	0.2	6
Contract length (in lane-miles)	58.557	98.309	0.06	869
Contract cost (in 2007 US dollars)	2,705,997	1,644,528	51,940	21,000,000
Traditional Contracts (Rehabilitation):	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	1.617	2.012	0.164	6
Contract length (in lane-miles)	35.493	88.606	0.11	880.5
Contract cost (in 2007 US dollars)	3,280,095	2,100,970	10,000	21,000,000
Design-Bid-Build:	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	2.442	2.044	0.21	6
Contract length (in lane-miles)	44.557	30.379	1.14	105
Contract cost (in 2007 US dollars)	17,067,414	12,094,874	50,000	59,500,000
PBCs:	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	6.256	5.282	1	25
Contract length (in lane-miles)	3,768.62	5,020.93	12.427	22,500
Contract cost (in 2007 US dollars)	80,025,776	82,955,023	58,000	378,000,000
Lane Rentals:	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	2.661	2.035	0.21	5.9
Contract length (in lane-miles)	40.103	28.511	1.19	106.5
Contract cost (in 2007 US dollars)	14,848,650	13,900,105	44,500	58,000,000
Warranties:	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	3.227	1.775	0.22	6.1
Contract length (in lane-miles)	56.79	29.229	1.2	123
Contract cost (in 2007 US dollars)	28,490,056	15,572,754	55,000	66,000,000
A+B+I/D:	Mean	St. Dev.	Minimum	Maximum
Contract duration (in years)	2.579	2.345	0.25	9.19
Contract length (in lane-miles)	40.205	33.298	1.16	117
Contract cost (in 2007 US dollars)	19,432,091	18,610,899	50,000	64,500,000

Table 4.3 shows that the longer the PPP contract duration, the higher the likelihood of having cost savings in traditional maintenance, lane rentals, and A+B+I/D contracts and the lower the likelihood of having cost savings (the higher the likelihood of experiencing loss) in traditional rehabilitation, design-bid-build, and warranty contracts. Also, for short-period contracts (less than two years) there is a lower likelihood of achieving cost savings with PBC.

Table 4.3. Binary Probit Model Results for Cost Savings or Loss by PPP Approach

Variable	Traditional Maintenance	Traditional Rehabilitation	Design-Bid-Build	PBC	Lane Rentals	Warranties	A+B+I/D
Constant	-0.688 *	1.847 **	1.942 ***	-4.031 ***	0.526 ***	1.795 **	3.742 ***
Contract duration (years)	0.433 **	-0.136 ***	-0.212 **		0.110 ***	-0.015 *	0.177 **
Contract duration (1 if less than 2 years, 0 otherwise)				-1.774 **			
Contract length (in hundredths of lane-r	0.0002 *	0.003 **	0.017 **		0.001 **	0.021 *	0.019 *
Contract length (1 if greater than 200 lane-miles, 0 otherwise)				2.044 ***			
In-house cost (in million $)			0.002 **			-0.003 **	
Activity indicator variables:							
Bridge-tunnel or culvert-gutters-drainage		-0.299 **					-2.384 ***
Pavement repair		0.110 ***				-0.384 **	
Guardrail repair						-0.526 ***	
Culvert-gutters-drainage						-0.681 **	
Electrical system maintenance	-4.323 ***						
Landscape or vegetation/ tree maintenance or litter removal	-1.197 **						
Crack sealing, Pothole repair				4.197 **			
Emergency Facilities Maintenance/Response				-3.258 **			
Number of Observations	76	94	43	99	40	139	79
McFadden Pseudo Rho-squared	0.66	0.52	0.49	0.58	0.51	0.72	0.43

* *Significant at the 0.90 level of confidence.*
** *Significant at the 0.95 level of confidence.*
*** *Significant at the 0.99 level of confidence.*

With respect to the contract length, the results suggest that the longer the PPP contract length, the higher the likelihood of having cost savings in all PPP approaches (except PBC), with the warranties, A+B+I/D and design-bid-build approaches having the stronger effect. Also, for contracts that have long lengths (greater than 200 lane-miles), it was found that there is generally a higher likelihood of achieving cost savings in PBCs. The results suggest that the longer the length of an outsourced road section, the higher the probability of having cost savings and the higher the expected cost savings.

The results also suggest that rehabilitation activities such as bridge-tunnel or culvert-gutters-drainage decrease the likelihood of cost savings (i.e., the higher likelihood of experiencing loss) in traditional rehabilitation and A+B+I/D contracts. It can also be observed that the A+B+I/D contracting approach has a stronger influence on the

likelihood of experiencing a loss, compared to the influence of the traditional rehabilitation approach.

Traditional rehabilitation activities such as pavement repair, were observed to be associated with an increase in the likelihood of cost savings; whereas, for warranty contracts, the impact is the opposite (i.e., it decreases the likelihood of cost savings and there is more likelihood of a loss). Also, the inclusion of guardrail repair and culvert-gutters-drainage rehabilitation activities in warranty contracts appears to decrease the likelihood of cost savings. Traditional maintenance activities, such as electrical system maintenance, in traditional contracts were found to have a stronger direct impact on the likelihood of experiencing loss compared to landscape or vegetation/tree maintenance or litter removal.

Finally, in PBCs, activities such as crack sealing and pothole repair were found to have a strong and direct impact on the likelihood of cost savings. On the other hand, emergency facilities maintenance/response in PBCs had a strong and direct impact on the likelihood of experiencing loss.

4.5.2 Cost Savings (or Loss) Amount

Next, the amount of cost savings (and loss) was analyzed using a linear regression model. Table 4.4 presents the regression model estimation results. It can be observed that all variables included in the model are statistically significant and the signs are intuitive. It can be observed that the constant terms for all the contracts in the PPP approach were positive.

The model results suggest that the duration of the contract is directly related to traditional maintenance, PBC, lane rentals and A+B+I/D contracts, whereas an inverse relationship was found for traditional rehabilitation, Design-Bid-Build, and warranty contracts. The results suggests that a unit increase in duration of contracts (i.e., one year), would be expected to yield 1%, 2.5%, 0.4%, and 0.2% increases in the percent cost savings in the traditional maintenance, A+B+I/D, PBC, and lane rentals, respectively. On the other hand, one unit (i.e., one year) of increase in the contract duration would be expected to result in 2.4%, 1.0%, and 0.1% increase in the percent of loss in warranties, Design-Bid-Build, and traditional rehabilitation contracts, respectively.

With respect to contract length, the results seem to suggest that traditional maintenance, traditional rehabilitation, warranties, and A+B+I/D contracts have direct impacts on cost savings. However, lane rentals were observed to have an inverse impact on cost savings. The results suggest that a unit increase of contract length (i.e., one lane-mile) would be expected to yield 0.6%, 0.3%, and 0.1% increases in the cost savings for traditional maintenance, traditional rehabilitation, and warranties, respectively; and also 0.2% increase in loss for lane rentals. It was also observed that PBCs with contract lengths of more than 600 lane-miles are associated with a 3.3% increase in loss.

Table 4.4. Linear Regression Model Results for Cost Savings or Loss by PPP Approach

Variable	Traditional Maintenance	Traditional Rehabilitation	Design-Bid-Build	PBC	Lane Rentals	Warranties	A+B+I/D
Constant	0.067 **	0.042 *	0.092 ***	0.047 ***	0.031 ***	0.172 ***	0.211 ***
Contract duration (years)	0.011 ***	-0.001 *	-0.009 **	0.004 **	0.002 **	-0.024 ***	0.025 **
Contract length (in hundredths of lane-r	0.006 *	0.003 *			-0.002 *	0.001 *	0.0004 *
Contract length (1 if greater than 600 lane-miles, 0 otherwise)				-0.033 **			
In-house cost (in million $)	0.001 *	0.002 ***	0.001 **		0.001 ***		
In-House cost (1 if greater than $25,000,000, 0 otherwise)				0.055 ***			
Activity indicator variables:							
Bridge-tunnel or culvert-gutters-drainage		-0.023 **					-0.102 **
Pavement or shoulder repair						-0.029 **	0.266 **
Guardrail repair or culvert-gutters-drainage						-0.131 *	
Landscape or vegetation/ tree maintenance or litter removal	-0.038 **			-0.094 **			
Rest areas maintenance	0.051 **						
Illumination Repair/Maintenance or Mowing				0.062 ***			
Number of Observations	76	94	43	99	40	139	79
Adjusted R-square	0.71	0.57	0.51	0.58	0.47	0.61	0.55

** Significant at the 0.90 level of confidence.*
*** Significant at the 0.95 level of confidence.*
**** Significant at the 0.99 level of confidence.*

Traditional maintenance and rehabilitation contracts, Design-Bid-Build, and lane rentals were found to have directly related to cost savings. Also, for project with in-house cost exceeding $25 million, corresponding PBCs yielded a 5.5% cost savings.

The results suggest that cost savings for bridge-tunnel or culvert-gutters-drainage were inversely associated with traditional rehabilitation and A+B+I/D contracts. In

words, traditional rehabilitation and A+B+I/D generally resulted in a 2.3% and 10.2% increase in loss, respectively. Pavement or shoulder repair activities for warranty contracts decreased the loss by approximately 3%; whereas, A+B+I/D increased the cost saving by 27%. Guardrail repair or culvert-gutters-drainage in warranty contracts were found to result a 13% loss.

Landscape or vegetation/tree maintenance or litter removal activities were observed to generally result in 4% and 9.5% decreases in cost savings for traditional maintenance and PBCs, respectively. Rest area maintenance was found to increase the cost savings of traditional maintenance contracts by 5%; and illumination repair/maintenance or mowing in PBCs increased the cost saving by 6%.

4.6 Chapter Summary

This chapter analyzed the factors that affect the likelihood of cost savings occurring and the amount of the percent cost savings and loss for all PPP contracting methods. The cost savings point of reference was the in-house cost of the same activities with the same characteristics. Binary probit and linear regression models were developed. For each model, a likelihood ratio test was conducted to determine whether different models should be developed for the U.S. and international contracts. In all cases, it was found that the U.S. and international data were not statistically different and should be modeled together. Tables 4.4 and 4.5 summarize the model estimation results, indicating the factors that may have a positive or negative impact on the cost savings likelihood and amount, respectively. The ↗ arrows indicate a positive relationship among the individual parameters and the dependent variables (positive effect on cost savings likelihood or amount), whereas the ↘ arrows indicates a negative relationship (negative effect on cost savings likelihood or amount).

The chapter implemented the fourth and most intricate step in the multi-criteria decision-making framework for contracting approach selection. At this step, the consequences of each contracting approach in terms of the established evaluation criteria are quantified by using established estimation models that predict the levels of these outcomes under a given set of circumstances. In the chapter, a case study was utilized to

illustrate this step. Binary probit and linear regression models were developed to address the likelihood that a given contracting approach will yield a certain value of the evaluation criterion (for purposes of illustration, the chapter used the cost savings outcome as the evaluation criterion due to data availability).

Table 4.5. Summarized Findings: Cost Savings Likelihood

Variable	Traditional Maintenance	Traditional Rehabilitation	Design-Bid-Build	PBC	Lane Rentals	Warranties	A+B+I/D
Contract duration (years)	↗	↘	↘		↗	↘	↗
Contract duration (1 if less than 2 years, 0 otherwise)				↘			
Contract length (lane-miles)	↗	↗	↗		↗	↗	↗
Contract length (1 if greater than 200 lane-miles, 0 otherwise)				↗			
In-house cost (in million $)			↗			↘	
Activity indicator variables:							
Bridge-tunnel		↘					↘
Culvert-gutters-drainage		↘					↘
Pavement repair		↗				↘	
Guardrail repair						↘	
Culvert-gutters-drainage						↘	
Electrical system maintenance	↘						
Landscape or vegetation/ tree maintenance or litter removal	↘						
Crack sealing, Pothole repair				↗			
Emergency Facilities Maintenance/Response				↘			

Table 4.6. Summarized Findings: Cost Savings Amount

Variable	Traditional Maintenance	Traditional Rehabilitation	Design-Bid-Build	PBC	Lane Rentals	Warranties	A+B+I/D
Contract duration (years)	↗	↘	↘	↗	↗	↘	↗
Contract length (lane-miles)	↗	↗			↘	↗	↗
Contract length (1 if greater than 600 lane-miles, 0 otherwise)				↘			
In-house cost (in million $)	↗	↗	↗		↗		
In-House cost (1 if greater than $25,000,000, 0 otherwise)				↗			
Activity indicator variables:							
Bridge-tunnel		↘					↘
Culvert-gutters-drainage		↘					↘
Pavement repair						↘	↗
Shoulder repair						↘	↗
Guardrail repair						↘	
Culvert-gutters-drainage						↘	
Landscape or vegetation/ tree maintenance or litter removal	↘			↘			
Rest areas maintenance	↗						
Mowing				↗			
Illumination Repair/Maintenance				↗			

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study presented a general multiple criteria framework for selecting the best delivery approach for a given project based on the project attributes and the expected outcomes of the project. A key aspect of the evaluation framework is to select the appropriate evaluation criteria and then to establish the requisite theoretical or empirical relationships in order to predict, for each alternative project delivery approach, the impacts of that alternative in terms of at least one evaluation criterion. The case study in this report used cost savings as the evaluation criterion to demonstrate the contracting approach evaluation framework due to the availability of cost savings data. Thus, the study used statistical and econometric techniques to model the empirical statistical relationships between cost savings on one hand, and the project on the other hand, for each project delivery approach (such as PPP and traditional approaches, and in-house delivery).

In the quantitative case study used to demonstrate the framework, the expected outcome (cost saving) associated with each contracting approach was determined using econometric models. The contracting approaches included innovative PPPs and in-house contracts. The projects used for the comparison generally had similar characteristics in order to provide a rational basis for comparison. The descriptive statistics provided some a priori expectations of the developed econometric models.

Besides their use to predict the outcomes of alternative contracting approaches to generate input for the multiple criteria framework application, the econometric analyses shed light on the factors that influence the performance of PPP contracts on the basis of the evaluation criteria (the likelihood and the amount of cost savings). The likelihood of cost savings occurrence was found to be directly related to contract length and road segments longer than 200 lane-miles compared to smaller projects, all else being equal – an obvious effect of scale economies. In addition, the in-house cost for Design-Bid-Build, crack sealing and pothole repair for PBCs, and contract duration for traditional

maintenance contracts, lane rentals, and A+B+I/D were all found to be directly related to cost savings likelihood, relative to projects outside each of these categories. On the other hand, the likelihood of a contract experiencing cost savings is inversely related to the contract duration for traditional rehabilitation, Design-Bid-Build, and warranties (and PBCs when their duration is less than two years) relative to projects outside each of these categories. The results also suggest that the amount of cost savings is directly related to contract length and in-house cost (for PBC, if it exceeds $25 million) – obviously due to scale economies. Also, for Design-Bid-Build contracts, a larger contract size (length of road section) was found to be generally associated with a greater likelihood of cost savings. The amount of loss (as opposed to cost savings) was found to be generally directly related to activities such as bridge-tunnel or culvert-gutters-drainage, pavement or shoulder repair (except for A+B+I/D where it is found to have a direct effect on cost savings), landscape or vegetation/ tree maintenance or litter removal, relative to other activities. For PBC contracts, projects of length exceeding 200 lane-miles were found to be associated with a greater likelihood of cost savings. Also, crack sealing and pothole repair activities were generally found to increase the likelihood of cost savings, relative to other work types, all else being equal. For lane rentals and A+B+I/D contracts, the results suggest that a greater likelihood of cost savings is associated with greater contract duration and contract length, relative to other PPP types or contracting approaches. It was also determined that PPPs that included activities such as bridge-tunnel or culvert-gutters-drainage were generally directly associated with greater cost savings compared to those without such activities. For PPPs with warranty contracts, however, projects that included pavement, guardrail, or culvert-gutters-drainage activities were found to be associated with greater likelihood of loss. A greater likelihood of loss was observed for traditional maintenance contracts with electrical system maintenance and landscape or vegetation/tree maintenance or litter removal activities, and also for PBCs with emergency facilities maintenance/response activities. For in-house projects, greater cost savings was found to be associated with a larger contract cost. For traditional maintenance contracts, PBC, lane rentals, and A+B+I/D, a longer planned contract duration was found to be associated with higher cost savings. Likewise, for traditional maintenance and rehabilitation contracts, warranties, and A+B+I/Ds, the contract size (in

terms of lane-miles), was observed to be directly related to higher cost savings, but the opposite effect was observed for traditional rehabilitation contracts, Design-Bid-Build, lane rentals, and warranties and for PBCs with contract size exceeding 600 lane-miles. For warranty contracts, inclusion of pavement or shoulder repair, guardrail repair or culvert-gutters-drainage, were found to be associated with a greater likelihood of loss, relative to such contracts that excluded these activities. Finally, for traditional maintenance contracts and PBCs, inclusion of landscape or vegetation/tree maintenance or litter removal, were found to be associated with higher loss, compared with contracts that did not include these activities.

Likelihood ratio tests for all the developed models were conducted to determine whether the estimated parameters (of each model) differed between international and U.S. PPP contracts. The results showed that, at a 90% level of confidence, the international and U.S. PPP contracts did not have any statistically significant differences. Hence, the joint models (including international and U.S. contracts) were estimasted.

5.2 Limitations of the Study

A limitation of the present study is that a small portion of the in-house projects' cost information (less than 5% , 18 contracts, of the total number of data points/contracts) was approximated, because there were minor differences in the contract durations and lengths (in all cases, no more than 4%). Since the differences were very small, the analysis was not rendered vulnerable to economy of scale distortions. Finally, the majority of the international contracts were performance-based, delimiting the effects of the other contracting methods only to U.S. specifications and characteristics. However, the differences between U.S. and international PBC characteristics were not found to be statistically significant; thus, it can be assumed that the same can be said of the remaining contracting methods.

5.3 Recommendations for Future Work

This study presented a framework for contracting approach selection and demonstrated one aspect of the framework. Future studies could address the other parts of the framework, With regard to the aspect of the framework that was addressed in this study,

some additional future refinements may be necessary. The presented methodology could be extended to other roadway maintenance and construction activities. Also, in this study the cost information was based on total final amounts. A cost segmentation approach is suggested for further study, where the elements defining the maintenance and rehabilitation costs are clearly separated, for example, as follows: personnel costs (field workforce and personnel's training), equipments costs (new or leased), fuel/power for equipment, equipment maintenance), material and resources costs, management costs (hiring and personnel management, general administration, administrative support), and accounting. As such, an in depth cost-effectiveness analysis could be conducted.

Finally, the methodology developed in this study addresses the call by researchers (Zhang, 2006) for an impartial, equitable, and thorough best value methodology upon which a rational and defensible contract award decision can be made. It is important that the contracting approach selection be made in an objective, transparent, and defensible manner. As such, agencies need to develop ways of communicating the results of multiple criteria analysis and similar methods for identifying the best contracting approach on the basis of their overall best value. This information is important to address the criticism that such methods have faced, such as the ambiguity in the results. It has been stated in past research that contracting companies have often questioned the best value-based decisions of their public client and are asking the following questions. How did the public client derive its decision on the basis of the various cost and non-cost criteria? What were the discriminators that led to their non-selection? How did the public client determine that the value perceived was worth the cost difference among the source selection finalists? Did they receive fair evaluations during the process or did the public client use the process to ensure that the party of its choice received the contract? Did the public client conduct a thorough analysis and fully document the source selection decision? (Mickaliger 2001). Hopefully, the results of the present has contributed towards the quest to answer questions such as these.

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APPENDICES

APPENDIX 1: Considerations for PPP Adoption Decision

Historically, the move towards maintenance and rehabilitation PPP contracts originated from one of several sources (Stankevich et al., 2005): (i) higher levels of government, (ii) external financing agencies, or (iii) the private sector. Following is an analysis of the type of decision-making process needed to move towards a PPP approach.

1. Pre-Bidding Stage

At the pre-bidding stage the following need to be considered:

(a) Reasons to consider a PPP approach. The government agencies need to clearly understand their main objectives in adopting a PPP approach, which may be one or more of the following:

(i) Need to cut costs.

(ii) Implement higher level government directive.

(iii) Manage the road network with fewer staff.

(iv) Receive long-term funding for the maintenance and/or rehabilitation program either from the government treasury or external financial sources that support a PPP approach.

(v) Improve customer satisfaction.

(vi) In response to the private sector's offer to deliver more cost effective maintenance services.

Depending on its main objective, the agency should determine the appropriate PPP format (i.e., extent (number of miles, km, or lane-miles, lane-km) and tenure of the contract, types of services. and range of assets to be outsourced.

(b) Existing legislation. The selected PPP format needs to comply with the country's legal and regulatory framework. Some aspects of the contract format may be dictated by the prevailing environment. In this case, the agency may need to promote the necessary changes to achieve the desirable format. For example, if the legislation permits a maximum two-year contract, the agency may start with a two-year contract. However, once the appropriate changes permitting longer-term contracts are approved in the legislation, the agency can move to longer-term contracts.

(c) Capacity (skills, expertise, etc.) and changing the role of the government agency. First, the government agency must be ready to switch from the role of a "micromanager" to that of a strategic manager, regulator, and auditor. Secondly, the agency has to acquire new skills and expertise to be effective in this new role. Some countries may decide to seek technical assistance

from countries more experienced in PPPs in order to build up their agency capacity. Others may find it more cost-effective to engage consultants for assisting with this role, provided the domestic consulting industry possesses the appropriate skills. Finally, the agency needs to identify what procedures require modification to match the selected PPP format. For example, a provision requiring annual funding for multi-year contracts should be incorporated in the agency's budget process to ensure stable funding for PPPs.

(d) Capacity and unionization of the contracting industry. The government agency needs to match the complexity of the PPP to the capacity of the contracting industry available in the country (Stankevich et al., 2005). Where the industry is less developed, it would make sense to start with shorter-term, simple PPPs (e.g., contracts for routine maintenance or street lighting only). In addition, the unionization level of the contracting industry needs to be taken into account. The prospective PPP format should not be perceived by the industry as depriving most contractors of business opportunities, while placing a privileged few in a dominant position. Therefore, it is essential that the contracting industry be engaged at an early stage in the process of moving towards PPPs and appropriately consulted to adjust the format to suit local circumstances.

2. Bidding and Implementation Stage

At the bidding and implementation stage, the following issues need to be considered:

(a) Inventory of potentially contracted assets and determination of their condition. Prior to developing an "Invitation for Bids," the agency should arrange the inventory and collection of data. There is a need to:

(i) Accurately determine the conditions of the road assets to be contracted out,

(ii) Define the performance indicators in the contract,

(iii) Undertake preliminary cost estimates, and

(iv) Specify a monitoring process.

(b) Performance standards. Performance standards should be established for each asset to be contracted out. The selection and definition of standards should be based on:

(i) Road user needs,

(ii) The expectation of the client to have assets back on contract completion at the same level as they were contracted out or better, and

(iii) Affordability or the level of funding available.

The agency should avoid setting performance standards too high because ambitious goals might significantly affect the bid price. The definitions of performance standards should be simple, clear, easy to understand and achievable by the contractor.

(c) Methodology to measure performance standards. The agency needs to determine the methodology (i.e., the methods and tools) which will be applied to measure the performance standards for each contracted service. It should be simple and inexpensive. The methodology should be clearly and accurately described in the contract to prevent any misunderstanding from the contractor's side and avoid potential disputes. The contractor's performance is usually evaluated at three levels (Stankevich et al., 2005): management, long-term, and operational. Management performance standards drive the planning, management, and implementation aspects of the contract. They usually incorporate plans for quality, traffic, health, safety, and reporting requirements. Long-term performance standards relate to the overall condition of the pavement, roughness, skid resistance, texture, rutting, surface life, structural conditions, etc. and "drive" the contractors' maintenance and rehabilitation interventions. Operational performance standards apply to the daily serviceability of the road network being maintained and include conditions of the pavements and road furniture.

(d) Payment conditions. The payment conditions should be linked to the performance standards described in the contract. The contractor may be paid in a fixed price lump sum price in case of compliance with these standards. Periodically, penalties for non-compliance should be set for each indicator and deducted from scheduled payments to the contractor.Building in a reward mechanism in the contract is recommended to reward the contractor if retaining or exceeding the desired level of service for a sustained period is managed. Such a mechanism provides an incentive to the contractor to innovate and deliver high standards.

(e) Contract conditions. As a PPP may involve a significant shift in risk and management responsibilities to the contractor, the conditions of the contract should clearly define the new roles of the client and the contractor. They should clearly identify all potential risks and allocate these to the party that can manage them best. This applies, for example, to risks in predicting the growth in traffic and equivalent standard axles loads and risks for unpredictable costs under circumstances that are beyond the contractor's control (Stankevich et al., 2005).

(f) Preliminary cost estimates. The agency should prepare preliminary estimates for services to be contracted out under a PPP. The objective is to obtain a benchmark price for the contract against the bids with which it will be compared later.

(g) Bid evaluation and selection. Several criteria have been used for selection of contractors under PPP, based on the following:

(i) Price only or price and non-price criteria,

(ii) Pre-qualification of bidders or post-qualification, and

(iii) Joint evaluation of technical and cost proposals or short listing of bidders based on the evaluation results of technical proposals prior to the evaluation of cost proposals.

If both price and technical criteria are taken into account, then the agency should determine:

(i) Technical criteria to be applied,

(ii) Weight of technical criteria vs. price, and

(iii) Whether the winner will be selected based on the lowest bid, the highest score for the technical proposal, or the highest overall score for the both cost and technical proposals.

Table A.1. Penalties for Non-Compliance with Mandatory Requirements: Case of CREMA in Argentina, 2004-2005 [Source: Stankevich et al., 2005]

Section	Parameter	Performance Requirements	US$ equivalent
Subject to rehabilitation	Pavement Roughness	IRI max.=3 (AC) IRI max.=3.5 (S.T./RC)	250/week/km
	Pavement Rut Depth	1 cm max.	500/week/km
	Pavement Edge Break	0 cm	500/week/sector
	Pothole>2.5 cm	100% patched	500/day/pothole
	Cracking	100% sealed, and < 15% type 2 or 4	250/week/km
	Concrete pavement joint cracks	100% sealed	250/week/km
	Ravelling	0%, and <2% if surface treatment	250/week/km
Subject to Routine Maintenance	Edge Break	3 cm max	500/week/sector
	Cracking	100% sealed up to type 4	250/week/km
	Pothole	100% patched	500/day/pothole
	Ravelling	100% patched	250/week/km
	Paved Shoulders	Pothole/raveling=0 Edge break=0 Rutting<12 mm Cracks sealed up to type 4	500/week/km
	Unpaved Shoulders	No erosion, no rut, good transversal slope; edge break<2 cm; width>=3 m.	500/week/km
	Bush Clearing	Bush height<15 cm over 15 m	50/ha/week
	Culvert/drains/bridge cleaning	Clean/Unobstructed	250/day/km
	Cleaning of Right-of-Way	No debris; maintain green areas	250/day/km
	Vertical Signs	Well maintained and visible day and night	50/day/sign
	Lighting	Well maintained	50/day/light
	Horizontal Marking	Well maintained and visible day and night	100/day/line/km
	Guardrails	In good condition	500/week/location

Notes: 1. Penalty application are waived during initial 3 months of contract, generally; 2. Roughness on sections subject to routine maintenance is measured for indicative purposes only; 3. 10% of the contracted network has to be inspected every month, by individual segments of 2 km; 4. Reduction of original thickness of wearing course not allowed; 5. Milling of rut allowed only if material milled is replaced; 6. Surface treatment over Asphalt concrete not allowed; 7. When crack type > 4, sealing may be replaced by other treatment (ex: slurry seal, micro-asphalt); 8. One month routine maintenance = USD 200/month*200 km= USD 40,000/month, on average per network; 9. Ex: 1 pothole remaining open every 10 km during one week = 500*7 days*200/10 km = USD 70,000 penalty; 10. 4 horizontal marking lines missing over 10 km during 1 week = 4*100*7*10=USD 28,000 penalty; 11. More than half of the above penalty parameters related to road safety concerns (risk of accidents)

Non-price criteria that have been used in PPP procurements include the management team, relevant management and technical experience, past performance, methodology suggested, and technical skills available. . Due to the potential allocation of management responsibilities and risks to the contractor by a PPP, some countries opt for a "best value" approach in selecting a "winner," arguing that the "lowest bid" approach does not ensure relevant experience and appropriate understanding of the PPP approach. However, these concerns can be addressed through appropriate pre- or post-qualification. Pre-qualification of bidders based on clearly defined technical, financial, and past experience, and other relevant criteria, is usually the preferred approach. The use of a consortium of contractors and consultants is encouraged because of the total asset management concept inherent in such contracts. The World Bank guidelines (World Bank, 2004) recommend that contracts should be awarded to the bidder who meets the appropriate standards of capability and resources and whose bid has been determined: first, to be substantially responsive to the bidding documents, and second, to offer the lowest evaluated cost.

(h) Performance and payment security. Legislation in some countries may require performance security based on the contract value. In the case of multi-year PPPs, this requirement may become a significant issue since it could tie up a contractor's security capacity and restrict the number of potential bidders on other contracts. To overcome this problem, some countries started with shorter-term PPPs, whereas in others, authorities require either a two-year bond renewable annually (e.g., in Texas, U.S.) or one-year value bond (e.g., in Washington, DC, U.S.). In the U.S., bonds are a common form of security. Alternatively, contracts may provide for a percentage of each periodic payment to be held as retention money until final acceptance of the services (World Bank, 2004).

(i) Quality assurance program. Monitoring and evaluation of the contractor's performance should be arranged to ensure the contractor's compliance with the performance specifications. The government agency should determine the manner and frequency of monitoring inspections, the composition of the joint inspection panel, the party responsible for arranging regular inspections, the procedures of scheduling and arranging inspections, the rules of selecting road segments to be tested, etc. (Zietlow, 2005). Typically, the inspection panel may consist of the representatives of each concerned party: agency, contractor, and supervisor. Since performance standards, which are typically presented in a PPP, generally reflect the road users' needs, the road users could also participate in performance monitoring to voice their concerns about the quality of service delivered.

Table A.2. Weight of Price and Non-price Criteria in the PPP Procurement Process (PBC Summary Presented) in Different Countries [Source: Pakkala, 2002]

Country	Weight of Selection Criteria
Australia, Sydney, and Tasmania	50% - price, 50% - others (varies with territory)
Alberta, Canada	78% - price, 22% - others
British Columbia, Canada	40% - price, 60% - others
Ontario, Canada	90% - price, 10% - others
U.K.	30-40% - price, 60-70% - others
Finland	75% - price, 25% - others
New Zealand	50% - price, 50% - technical criteria
Sweden	90% - price, 10% - others
U.S.A.	50% - price, 50% - others and negotiated

(j) Partnering. A partnering agreement should be completed between the agency, contractor, and supervisor as many PPP-related issues need attention from each party to ensure delivery of the desired level of service (Stankevich et al., 2005). This agreement is not about "execution of the client's instructions," but about satisfying road user needs, which requires commitment from all the parties involved. The partnering process allows the parties to establish more effective working relationships and better understand the associated risks. In some countries, the partnership agreement is signed by the management, contractors, and supervising agencies.

Table A.3. International Contracts' Data Types and Sources

Type of Contract ; Contract Duration & Extension ; Length of Outsourced Road Segments ; Outsourced Asset Types ; Contract's Cost ; Cost Savings:
World Bank: Resource Guide – PBC for Preservation and Improvement of Road Assets
http://www.worldbank.org/transport/roads/resource-guide/Country-Matix.htm
Contract's Cost Estimate ; In-House Cost ; Bid Information (Number of bids, Highest bid, Bid range):
World Bank: Resource Guide – PBC for Preservation and Improvement of Road Assets
http://www.worldbank.org/transport/roads/resource-guide/Case-Argentina.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Australia.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Brazil.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Canada.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Chad.htm http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/cases-and-pdfs/5_PBC_Denmark.pdf http://www.worldbank.org/transport/roads/resource-guide/Case-Estonia.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Finland.htm http://www.worldbank.org/transport/roads/resource-guide/Case-New%20Zealand.htm http://www.worldbank.org/transport/roads/resource-guide/Case-Peru.htm http://www.worldbank.org/transport/roads/resource-guide/Case-SerbiaMn.htm http://www.worldbank.org/transport/roads/resource-guide/Case-SouthAfrica.htm http://www.worldbank.org/transport/roads/resource-guide/Case-UK.htm http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/cases-and-pdfs/5_PBC_Uruguay.pdf http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/bidding%20docs/cambodia/Cambodia_13Dec04.pdf
Government of British Columbia – Ministry of Transportation – Highway Maintenance Contracts
http://www.th.gov.bc.ca/BCHighways/contracts/maintenance/hwy_maintenance_contracts.htm
Republic of Serbia – Road Directorate
http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/bidding%20docs/serbia/Serbia_Vol_%202_CoC&CD.doc
The United Republic of Tanzania – Ministry of Works – Tanzania National Roads Agency
http://www.worldbank.org/transport/roads/resource-guide/Docs-latest%20edition/bidding%20docs/tanzania/Tanzania_Bid_doc_Vol_2_2005.pdf
U.S. DOT – FHWA: http://www.tfhrc.gov/focus/jan05/01.htm
G. Zietlow's PBC for Road Management and Maintenance website: http://www.zietlow.com
Other Resources: Zietlow, 2004; Zietlow, 2005a; Zietlow, 2005b; Stankevich et al., 2005; Pakkala, 2005; Pakkala, 2002; Porter, 2002; PIARC, 2004; Williams, 2005.

Table A.4. U.S. Contracts' Data Types and Sources

FLORIDA
Type of Contract; Contract Duration & Extension; Length of Outsourced Road Segments; Outsourced Asset Types; Contract's Cost; Cost Savings:
World Bank: http://www.worldbank.org/transport/roads/resource-guide/Case-USA.htm#florida
Contract's Cost Estimate; In-House Cost; Bid Information:
Florida DOT – Asset Management: http://www.dot.state.fl.us/statemaintenanceoffice/asset.htm G. Zietlow's PBC for Road Management and Maintenance website: http://www.zietlow.com Other Resources: OPPAGA, 1999; OPPAGA, 2003; Segal et al., 2003.
MINNESOTA
All information acquired from:
Innovative Contracting in Minnesota 2000 to 2005 – Minnesota DOT: www.dot.state.mn.us
TEXAS
All Information acquired from:
Texas DOT: http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/results/awardedl.htm Tammy Booker Sims, P. E.
Type of Contract; Contract Duration & Extension; Length of Outsourced Road Segments; Outsourced Asset Types; Contract's Cost; Cost Savings:
World Bank: http://www.worldbank.org/transport/roads/resource-guide/Case-USA.htm#texas Zietsman, 2005.
VIRGINIA
ALL Information acquired from:
Virginia DOT: http://syip.virginiadot.org/LineItems.asp?syp_scenario_id=83&tab=fund&
Type of Contract; Contract Duration & Extension; Length of Outsourced Road Segments; Outsourced Asset Types; Contract's Cost; Cost Savings:
World Bank: http://www.worldbank.org/transport/roads/resource-guide/Case-USA.htm#virginia
Contract's Cost Estimate; In-House Cost; Bid Information:
Segal et al., 2003; VMS Inc., 2001; JLARC, 2001; Lande, 2005.
WASHINGTON D.C.
Type of Contract; Contract Duration & Extension; Length of Outsourced Road Segments; Outsourced Asset Types; Contract's Cost; Cost Savings:
World Bank: http://www.worldbank.org/transport/roads/resource-guide/Case-USA.htm#dc
Contract's Cost Estimate; In-House Cost; Bid Information:
Segal et al., 2003; FHWA, 2002, 2004; M. Baker Jr. Inc., 1999; Robinson et al., 2004, 2005.
ALASKA
Frank T. Richards, P.E. ; Alaska DOT: http://www.dot.state.ak.us/
INDIANA
Indiana DOT: http://www.in.gov/dot/div/contracts/