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Exploring Performance-Based Contracts: A Good Option to Address Long-Term Road Maintenance in California?

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California State University Transportation Consortium

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16. Abstract

Performance-based contracts (PBCs) used in road maintenance provide flexibility for considering new materials, design, and technology to achieve predetermined performance targets. Several states in the U.S. have already used these types of contracts in road maintenance, and their experience can inform the use of PBCs in California. The objectives of this research are twofold. First, identify the benefits and challenges of PBCs compared to traditional contracts. Second, explore the main aspects of PBCs implementation for road maintenance and relate them to California's context. To this end, deductive-inductive content analysis was conducted on 84 peer-reviewed articles published between 1998 and 2023. Findings of this research identified the main benefits of PBCs to be: (1) cost savings, (2) improved work/service quality, and (3) reduction in risk to the transportation agency through the transfer of responsibility to the contractor. The main challenges were found to be: (1) the need for training and a shift in mindset from traditional contracting forms to PBCs, (2) the need to establish trust between contracting agencies and contractors, and (3) the temptation for contractors to abuse the system. Research findings highlighted "procurement," "performance indicators," and "incentives/disincentives" as the three major themes to consider in PBC implementation. California does not have a history of using performance-based contracts for road maintenance. Results from this research may be the first stepping stone to initiate the decision-making process to use these types of contracts for road maintenance.

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1. Introduction

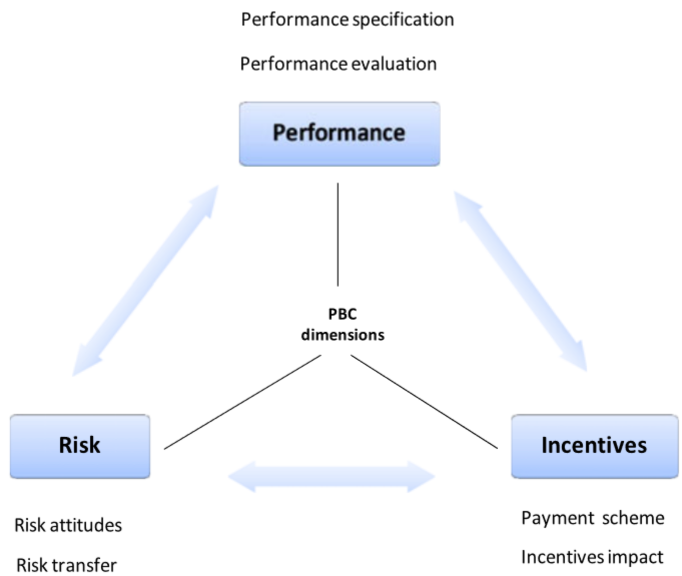
Senate Bill 1 (SB1)[1] aims to "fix neighborhood streets, freeways, and bridges in communities across California" (State of California, 2021). The purpose of the projects developed under this framework is not only to fix current deficiencies, but also to provide the effective long-term performance of roads and bridges. Thus, in these projects, enhancing long-term performance is a primary goal, and these goals are used by public agencies to select each project's contracting strategy. In fact, lifecycle issues such as costs and maintainability must be considered when selecting the contracting strategy (Touran et al., 2009).

In the 2019 Report Card for California's Infrastructure,[2] California has the second-worst roads in the country. "Fifty-five percent (55%) of the major urban roads in California are in poor condition." This report also indicates that SB1 provides the revenue needed for maintenance, but more must be done. In 2018, roads faced an $85 billion funding gap over the next ten years. To address this issue, it was recommended that the state explore new and innovative funding models, including increased participation from the private sector.

In contrast with traditional contracts, Performance-based Contracts (PBCs) consider payment for the construction, management, and maintenance of road assets explicitly linked to the contractor successfully meeting or exceeding a clearly defined number of performance indicators (Wirahadikusumah et al., 2015). In other words, these types of contracts use performance specifications, where the specifications do not direct the contractor on what, how, or when to do the work, but they clearly specify the performance that needs to be achieved (Kishor Shrestha, 2023). According to Selviaridis & Wynstra (2015), PBCs can be conceptualized in a three-dimensional model based on the concepts of performance, incentives, and risks (Figure 1).

[1] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB1.
[2] https://infrastructurereportcard.org/state-item/california/.

Figure 1. PBC Three-dimension model by Selviaridis & Wynstra (2015)



Performance refers to the requirements for specifying, measuring, evaluating, and reporting performance. Incentives relate to the payment structure regarding rewards and/or penalties. Finally, risks consider the risk of transferring from the owner to the contractor, given that the payment and reward/disincentives are tied to the contractor's performance. This approach leads to considering the duration of PBCs as a critical factor for both contractors and owners. PBCs can last between three to five years in agencies with less experience in these types of contracts and over ten years in more experienced agencies (Kishor Shrestha, 2023).

Previous studies have analyzed the use of PBCs by public administrators in other states and countries. For example, since the early 2000s, Florida has used the asset maintenance contracting program, where the contractor's performance is assessed through the asset maintenance contractor performance evaluation report (AMPER). Fuller et al. (2018) surveyed and interviewed 50 Florida Department of Transportation (FDOT) officials and 27 contractors involved in this program. The results highlighted the need for partnering between DOTs and contractors, for having a shared-risk model, and the relevance of having a well-defined scope and quantifiable performance measures. Another example is the Virginia Department of Transportation (VDOT). In this case, Ozbek & de la Garza (2011) provided a comprehensive evaluation of VDOT's experience with their first performance-based road maintenance contract. The results of the analysis over the period of six years gave insight into seven key issues that any state Department of Transportation (DOT) should consider when using PBCs in road maintenance: (1) tying payments to the contractor's actual performance, (2) generating a detailed baseline of road condition information, (3) using performance targets that increase over the contract period, (4) establishing a performance target for every item included in the contract, (5) having several inspections per year, (6) developing a standard rating procedure for all the elements, and (7) developing objective, quantifiable, and easy to measure performance criteria.

Another example is the Utah Department of Transportation (UDOT), which implemented a PBC for pavement markings. The results of ten interviews conducted on UDOT personnel showed a prominent level of agreement regarding the effectiveness of PBCs in contrast with traditional contracting. Idaho, Maryland, New Mexico, Texas, Montana, and Washington, D.C. have also used PBCs to maintain their safety rest areas along highways (National Cooperative Highway Research Program, 2009).

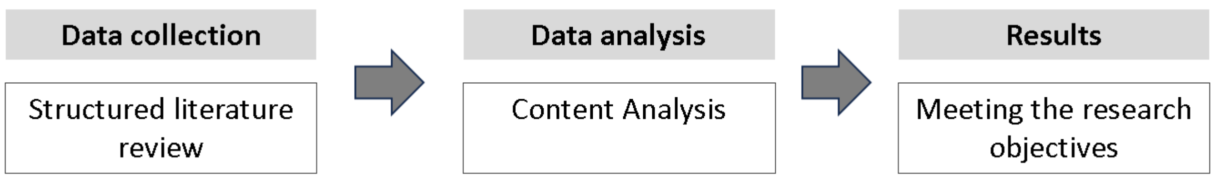
Besides the use of PBCs by different DOTs across the U.S., there is little research that addresses the main benefits, challenges, and specific aspects to consider when using PBCs and how they relate to California's road maintenance. This research aims to explore PBC as a contracting strategy to facilitate the application of new materials, design, and technology to address long-term road maintenance in California and contribute to Objective 3 of the California Senate Bill 1 by (1) identifying the benefits and challenges of PBCs compared to traditional contracts and (2) exploring main aspects to consider when implementing PBCs for road maintenance and relating them to California's road maintenance.

2. Research Methodology

This research aims to identify the benefits and challenges of PBCs compared to traditional contracts. It also explores the main aspects to consider when implementing PBCs for road maintenance and relates them to California's road maintenance.

The research followed a three-step process (Figure 2). First, a structured literature review was performed to gather peer-reviewed articles that represent academic research on the use of PBCs in DOTs worldwide. Next, a deductive-inductive content analysis was performed to draw out common threads in the reviewed documents and develop answers to the research questions. Finally, answers to the research questions were elaborated.

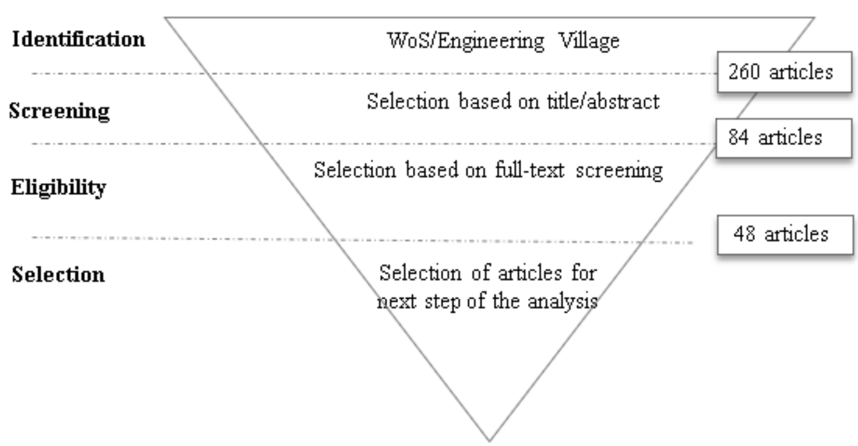
Figure 2. Research Methodology



2.1 Structured Literature Review

Data collection for this research was completed through a structured literature review following the four-step methodology (Figure 3) based on the preferred reporting items for systematic reviews and meta-analysis (PRISMA) approach (Moher et al., 2010).

Figure 3. Structured Literature Review. Four-step Approach



Identification

The first step in the structured literature review is data identification. Web of Science and Elsevier's Engineering Village platforms were chosen for the initial collection of published articles, since they provide access to a wide range of databases. Searches were conducted using the keywords "performance-based contracts AND highways". The Boolean operator AND was used to exclude results for performance-based contracts in unrelated fields (e.g., social services). These initial searches resulted in a total of 260 records identified: 218 from Engineering Village and 42 from Web of Science.

Screening

The screening process resulted in the elimination of articles in three categories: duplicate articles, inaccessible articles, and unrelated articles. Duplicate articles result from overlap in the databases accessible through the Web of Science and Engineering Village. When the list of articles retrieved from the two databases was compared, 16 duplicate articles were eliminated. Articles were excluded for inaccessibility if the researchers were unable to retrieve them due to licensing restrictions, a lack of digitized copies (especially for older articles), or technical errors that prevented access. Eighteen articles were excluded for inaccessibility. The remaining articles were screened for relevance by reviewing article titles and abstracts. Articles that were unambiguously unrelated to the research topic of highway PBCs were excluded. This step eliminated 142 articles. After the screening process was completed, 84 articles remained for analysis.

Eligibility

Eligibility determination was conducted by downloading all the articles that passed the screening stage and completing a full-text analysis. The contents of each article were briefly summarized and evaluated for relevance to the research topic. In this stage, 36 articles were deemed to be unrelated to highway PBCs and were excluded from the analysis.

Selection

The result from this stage of the structured literature review was 48 published articles that were considered relevant to the research topic and passed through to the content analysis phase.

2.2 Content Analysis

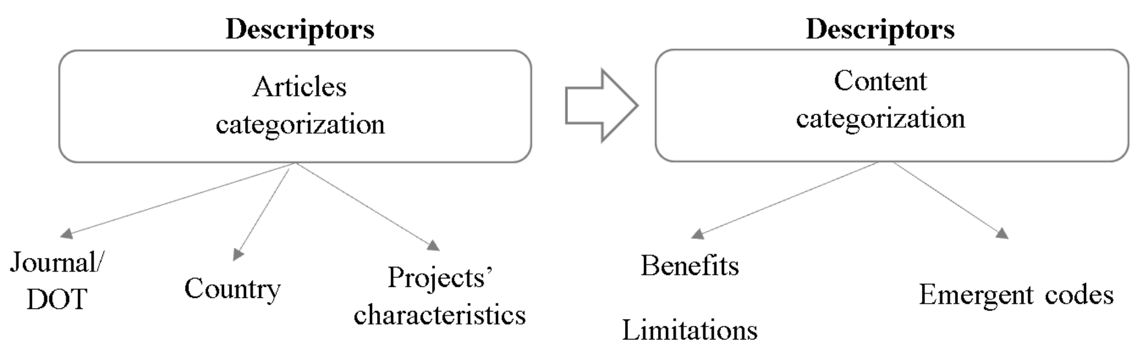
According to Smith (2000), "content analysis is a technique used to extract desired information for a body of material by systematically and objectively identifying specified characteristics of the material…[thereby] yielding unbiased results that other qualified investigators can reproduce". The ultimate goal of content analysis is to produce valid inferences that provide answers to research questions (Krippendorff, 2019). The articles gathered from the structured literature review formed the body of data for the content analysis phase of this research.

Spearing et al. (2022) defined hybrid content analysis as an approach to content analysis that mixes deductive and inductive design. In deductive content analysis, the authors use a predefined coding scheme based on predefined theory or knowledge. In inductive content analysis, researchers generate new or emergent themes from the text. The hybrid approach considers both predefined and emergent codes.

This project's content analysis followed this hybrid approach. Predetermined codes were used based on the first research question. These codes were "Challenges" and "Benefits". New relevant themes were sought during the inductive content analysis process (related to the second research question). As each new piece of data was analyzed, new categories of comparison emerged, which required reevaluating earlier data in a new context.

The researchers used the qualitative analysis software Dedoose to store the articles and conduct the content analysis. All the articles were assigned descriptors, which are the document metadata providing information about the journal where the article was published, the country, and the project's scope of work (e.g., maintenance or new construction). Articles were then analyzed using codes. Coding applies tags to text that describes a particular approach or finding from a data source. Three codes emerged (in addition to the predetermined codes of "Challenges" and "Benefits") as likely to provide information that could answer the research questions.

Figure 4. Content Analysis Descriptors and Codes



3. Results & Discussion

This section presents and discusses the findings of this study. The results of the structured literature review and content analysis are included, and a discussion on how the results obtained relate to California road maintenance is summarized.

3.1 Results

Articles per year and journal

Figure 5 shows the publication years of the eighty-four articles retrieved on PBCs. The publication dates of the articles range from 1998 to 2023. The number of publications increased between 2002 and 2017. For the last five years, the growth rate has remained stable at the maximum value per year in the historical record.

Figure 5. Number of Articles per Year of Publication

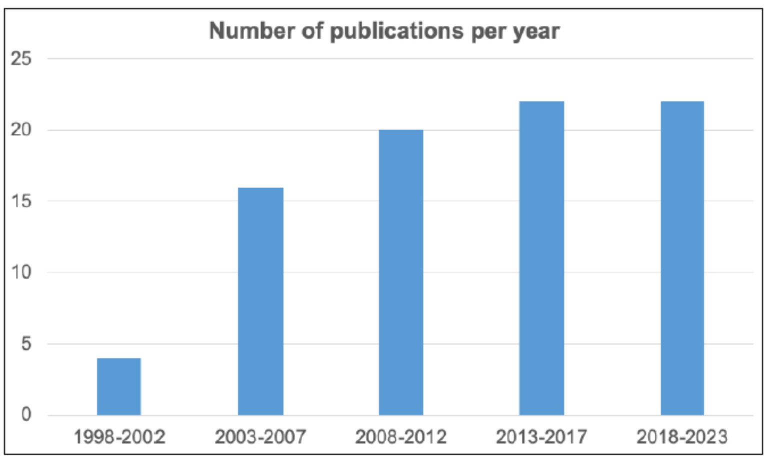
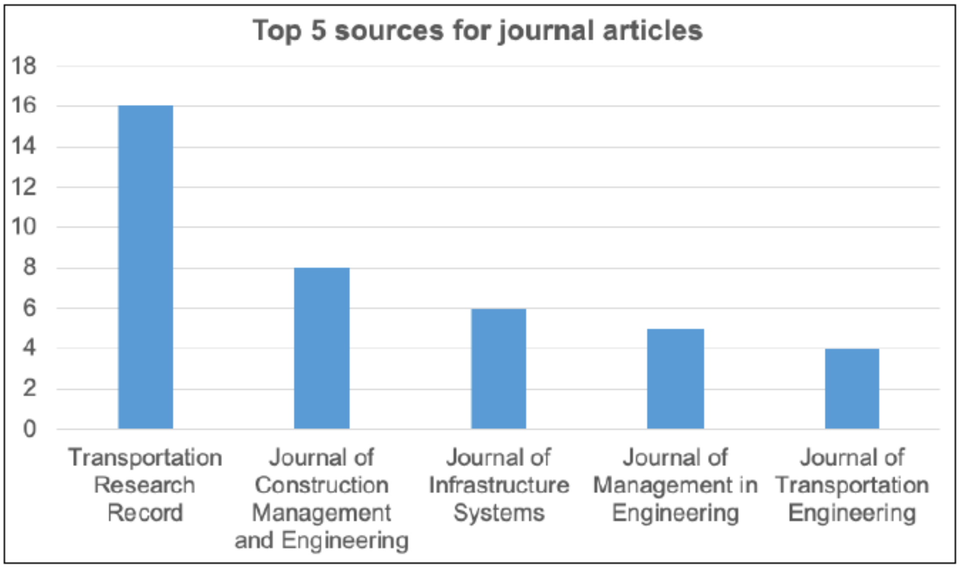


Figure 6 summarizes the number of relevant articles identified per journal. Forty-six percent of the articles were published in the following five peer-reviewed journals: *Transportation Research Record*, followed by the *ASCE's Journals of Construction Engineering and Management*, *Infrastructure Systems*, *Management in Engineering*, and the *Journal of Transportation Engineering*.

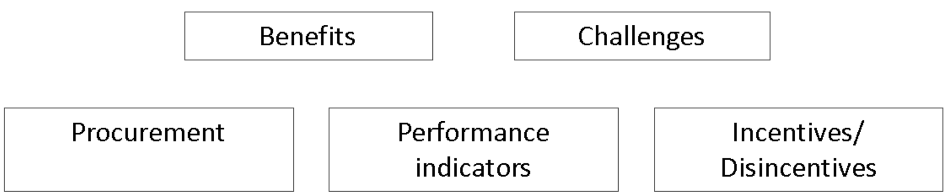
Figure 6. Number of Articles per Journal



Content Analysis Findings

The content analysis of the forty-eight selected articles resulted in five main themes: benefits, challenges, procurement, performance indicators, and incentives/disincentives.

Figure 7. PBC 5 Main Themes



Benefits

The benefits of PBCs were discussed in twelve articles. Three primary benefits of PBCs cited in the literature are cost savings, improved work/service quality, and reduction in risk to the transportation agency through the transfer of responsibility to the contractor. Cost savings through PBCs may be achieved in at least two ways. First, PBCs may allow transportation agencies to reduce overhead by eliminating in-house positions, equipment, or facilities (Anastasopoulos et al., 2010; Cabana et al., 1999; Stenbeck, 2009). Second, the longer duration of PBCs allows contractors to implement a lifecycle costing approach for assets under their management, which can reduce the long-term cost of maintaining the highway (Fallah-Fini et al., 2012; Ozbek & de la Garza, 2011; Pakkala, 2007). A more extended duration contract with predictable cash flows also opens the door to more financing options that can reduce long-term costs (Anastasopoulos et al., 2010; Damnjanovic et al., 2018).

In terms of the magnitude of cost savings, Pakkala (2007) reported cost savings between 10% and 40% based on a survey of 14 PBC programs across the globe. Stenbeck (2009) reported savings of 25–30% with the adoption of PBCs in Sweden in contrast to the United States and Canada, where cost savings are "near zero". Anastasopoulos et al. (2010) analyzed 89 PBCs for cost savings using a linear regression model. Seventy-eight of the contracts resulted in cost savings, and eleven resulted in a loss. Cost savings under PBCs increased for projects that were large, long, incorporated many activities, or were related to crack sealing, pothole repair, or mowing. Other factors increasing the likelihood of cost savings included projects that are highly competitive (attracting many bidders), have long extension periods, cover long road segments, and involve the repair or maintenance of roadway lighting.

Improved quality of work/service has been reported under PBCs in several contexts. In Spain, highways operated by contractors with safety incentives written into PBCs resulted in reduced accident frequency compared to public highways (Rangel & Vassallo, 2015). In the Virginia DOT PBC pilot program, the level of service achieved by the contractor equaled or exceeded the performance of highway sections maintained by the traditional in-house approach for all fence-to-fence asset groups (Ozbek & de la Garza, 2011). In Sweden, a rail network maintained under a PBC saw a decrease in train delays and the number of errors (Stenbeck, 2008). However, not all parties perceive higher quality work under PBCs. When surveyed, Florida DOT employees expressed slight disagreement with the statement that PBCs improve the level of service of highways (Fuller et al., 2018). While this perception may or may not be grounded in quantifiable data, it does suggest that the benefits of PBMCs should not be assumed without cause.

PBCs can benefit both the contracting agency and the contractor through the transfer of risk to the contractor. The contracting agency benefits by reducing exposure to risk that may arise due to unforeseen events such as unusual weather, labor disputes or material shortages, while the contractor benefits through greater managerial control over methods and the market incentive to innovate in order to increase profit margin (Abu Samra et al., 2017; Anastasopoulos et al., 2010; Kim et al., 2010; Ozbek & de la Garza, 2011; Shrestha & Shrestha, 2022). However, the transfer of risk does have drawbacks. Highway agencies and their contractors must carefully determine the appropriate level of risk to allocate to each party and ensure that the pricing of the contract is appropriate to the level of risk assumed (Anastasopoulos et al., 2010; Damnjanovic et al., 2018).

Several studies cite the potential benefit of innovation and the introduction of new methods to the field of highway maintenance, yet specific examples of such innovative methods are not presented in the literature (Cabana et al., 1999; Fallah-Fini et al., 2012; Ozbek & de la Garza, 2011; Stenbeck, 2008). Whether or not PBCs quantifiably facilitate innovation more than traditional contracting methods remains an open question.

Challenges

The challenges of PBCs were discussed in fifteen articles. Broadly speaking, the literature on PBCs focuses on three critical challenges that must be overcome. First is the need for training and a shift in mindset from traditional contracting forms to PBCs. Second, the need to establish trust between contracting agencies and contractors, and third, the temptation for contractors to abuse the system.

Since PBCs are a relatively new contractual form and have only been used in a handful of jurisdictions, many highway agencies and contractors simply do not know how to do things differently from traditional contracting. Successful implementation of PBCs requires the adoption of a new culture in both public and private sectors that thinks in terms of performance-based models (Fallah-Fini et al., 2012). Highway agencies may be reluctant to give up control over projects, reduce in-house headcount, or shift from the role of specifying methods to administering contracts at a higher level of abstraction (Anastasopoulos et al., 2009; de la Garza & Arcella, 2013; Hartmann & Dewulf, 2009). Likewise, contractors may be used to operating under a great deal of control and scrutiny from the contracting agency, and not used to operating independently and proactively under the terms of a performance-based contract. Both parties need time to unlearn the old ways of working and adapt to a new paradigm, though this may be difficult if PBCs, traditional contracts, or hybrid approaches combining the two methods all continue to be used by the highway agency (Hartmann & Dewulf, 2009). Regardless, sufficient staff training is essential to introducing the novel requirements, specifications, and responsibilities of each party inherent to PBMCs (Fuller et al., 2018).

A major obstacle to the successful implementation of PBCs is the lack of trust between the contracting agency and the contractor. Agency personnel may suspect that the contractor will not meet the obligations of the contract or will try to abuse the contract in order to maximize profits (Damnjanovic et al., 2018; Fuller et al., 2018). The reduction in direct agency control, the transition from an active to a passive role, and uncertainty about the methods used by the contractor may also contribute to distrust among agency personnel (Hartmann & Dewulf, 2009). Since excessive monitoring or micromanagement of the contractor negates the benefits of a PBC, agency personnel must trust the contractor to uphold the terms of the contract and manage the asset ethnically, at least until given reason to believe otherwise (Fuller et al., 2018).

PBCs can only succeed if the contractor avoids the temptation to abuse the trust placed in them by exploiting the system. Many of these behaviors can be mitigated through careful planning and consideration of contract specifications. For example, contractors may be tempted to wait and repair an asset just before it is scheduled to be inspected, rather than maintain it throughout the contract period (Fuller et al., 2018). Highway agencies can avoid this by randomizing the time and location of inspections in a manner that is unpredictable. Contractors may also be tempted to skimp on resources and maintain an asset in the lowest acceptable quality, thus negating the cost-benefit improvements anticipated from PBCs (Hartmann & Dewulf, 2009). This challenge can be overcome by carefully specifying the contractual requirements in an unambiguous, quantifiable manner to ensure that the cost-benefit ratio for PBCs remains competitive with traditional contracting. Though agencies can mitigate some of these challenges through careful drafting of contract language and a robust system of financial incentives and penalties, contractors also have a duty to adopt an ownership mentality for assets they manage via performance-based contracts.

Procurement

Discussion of procurement was found in eight articles. Although one of the primary benefits of PBCs is lower costs than traditional contracting methods, the low-bid method should be avoided when procuring PBCs (Ahmed et al., 2012; Pakkala, 2007). The low-bid method is appropriate when methods are specified and contractor behavior is predictable, as in traditional contracting. For innovative contracting methods such as PBCs, the contractor's technical excellence, competence, and capabilities are paramount (Pakkala, 2007; Shrestha & Shrestha, 2022). The best-value method incorporates both the bid price and the contractor's technical capabilities to evaluate contracts with the goal of producing the highest quality work at the lowest price (Zhang et al., 2018). Different agencies use various weightings of price and technical prowess. For example, the United Kingdom puts a lower weight (30%) on price and favors contracts with high technical marks (Shrestha & Shrestha, 2022). Other agencies take a more balanced approach or lean in favor of lower bids. Pakkala (2007) distinguishes between an "Anglo-Saxon Model" that uses best value criteria, and a "Cold Climate Model" that uses low bid criteria or places much more weight on price than any other factor. The "Anglo-Saxon" agencies tend to use formulas with 50% or less weight on price.

Bid evaluation algorithms differ from agency to agency. A study of four transportation agencies identified two basic best-value methods that have been used for evaluation of PBC bids: adjusted price and weighted criteria (Ahmed et al., 2012). The weighted criteria algorithm weighs price and technical scores. The adjusted price method calculated a technical quality value as a reduction to the total bid price.

Another modification to the low-bid method is the use of contractor prequalification using a minimum threshold of technical competency. In this method, technical ability is not weighed in the bid evaluation process. Instead, all contractors who demonstrate technical competency to complete the job are considered, and the low bid is selected from among these. This method was favored by a group of subject matter experts in the United States evaluating the PBMC method for chip-seal projects (Shrestha & Shrestha, 2022). Even with prequalification, the low-bid method still may not produce an ideal result if a firm relies upon its reputation or a core group of highly competent professionals to meet the prequalification requirement. A large country-, province-, or state-wide area maintenance contract will require skilled, experienced employees spread throughout the geographic area covered by the contract, which cannot be captured using the low-bid method (Pakkala, 2007). Thus, the prequalification process will have to include assurances that the skills and competence to execute PBCs are widely dispersed in the contractor's organization.

Performance Indicators

Discussion of performance indicators is found in eleven articles. Four articles described performance indicators in the context of pavement projects. Commonly used indicators to measure the performance of a chip seal include raveling, bleeding, smoothness, texture, and cracks (Shrestha & Shrestha, 2022). The international roughness index (IRI) is a popular standard for quantifying the smoothness of a paved road surface. Virginia DOT uses a proprietary index—the Critical Condition Index (CCI)—to determine whether a road surface is deficient (Fallah-Fini et al., 2012). There is a concern that performance indicators are clear, specific, and measurable. Nonspecific or ambiguous qualitative performance indicators can lead to disagreement or contractual disputes between the contractor and the road department. The example below provides specific, quantifiable performance measures and a standard inspection method for the field.

Example from Jeong et al. (2014)

Asset class:

- Asphalt pavement
- Threshold values for performance indicators (for national highways with a 3-year warranty period):
- Cracking: 15%
- Rutting: 12 mm
- IRI: 3.7 m/km

Inspection method:

- Inspect the outer lane (required) and any additional lanes (if the condition appears poor).
- Divide the roadway into 2 km sections. Further divide into four 500 m segments. Randomly select one segment.
- Inspect segment (500 m) at 10 m intervals. Take a mean of 50 data points for performance indicators. Compare with threshold values.
- If the threshold values are exceeded, proceed with inspection of the entire 2 km segment. Contact contractor for repairs.

For PBCs that cover a wider range of activities than just pavement maintenance, a more complicated system of performance indicators must be developed. The Florida Department of Transportation (FDOT) developed an asset maintenance contractor performance evaluation report (AMPER) for its PBMC program (Fuller et al., 2018). This system accommodates up to fifty-three distinct performance indicators for contracted areas that may include the roadway itself, vegetation, bridges, lighting, signage, and highway rest areas. Each of these elements can be given different weightings depending on the requirements of the contract. Weightings should be based on the relative importance of each element of the highway system as determined by the transportation agency (Ozbek & de la Garza, 2011).

Prior to the advertisement of PBC tenders, the transportation agency should ascertain the baseline condition of the roadway that will be maintained under the contract. This will allow the agency to set realistic performance targets for the contractor and provide bidders with accurate information about the condition of the asset while they assemble their bid packages. If the baseline condition of the asset is poor, the transportation agency may choose to set dynamic performance targets that are low in the early years of the contract while the contractor brings the system up to specifications. As the contract proceeds into later years, the performance targets can also increase until the roadway conditions are at the desired level (Ozbek & de la Garza, 2011).

Incentives/Disincentives

Discussion of incentives and disincentives in PBCs occurs in nine articles. The selection of incentives that reward performance above and beyond the contractual specifications and penalties that withhold payment for work that fails to meet contractual minimums is a key component of performance-based contracts and must be considered in the precontact phase of the project (Abu Samra et al., 2017; Shrestha & Shrestha, 2022). To avoid disputes over payment, contract language regarding incentives and disincentives must be specific, and performance indicators must be "objective, quantifiable, and easily measurable" rather than simply qualitative (Ozbek & de la Garza, 2011). Documentation of any deficiency must be thorough and should include measurement data and photography of the deficient asset (Cabana et al., 1999). At the beginning of the contract, a "grace period" for the contractor to remedy existing deficiencies may be provided before the application of penalties.

While all PBCs incorporate penalty clauses, the use of incentives to reward exceptional work is less common. With a properly implemented incentive structure, contractor work may extend the life of the asset and provide a better experience to users (Shrestha & Shrestha, 2022). Incentives can also be used to improve highway safety or meet other social or environmental goals (Rangel & Vassallo, 2015; Selviaridis & Wynstra, 2015). Previous research suggests that a combination of incentives and penalties can improve contract performance and build trust between parties more effectively than penalties alone, although the optimal combination of incentives and penalties is a question in need of further research (Kim et al., 2010; Scharpff et al., 2021). Shrestha and Shrestha (2022) suggest that incentives/disincentives should be set between 4% and 5% of total contract value for chip seal projects, although penalties and incentives as high as 50% and 20%, respectively, have been observed.

Although PBCs shift much of the responsibility for the management and operation of an asset from the contracting agency to the contractor, the public agency remains the long-term steward of the asset and must ensure that it continues to function at an acceptable level for the public (Fuller et al., 2018). The contracting agency must be willing and able to step in and perform extraordinary work that the contractor is unable or unwilling to perform. Provisions for cancelation of the contract due to non-performance or persistent underperformance should be incorporated into the agreement in addition to penalty clauses (Cabana et al., 1999).

3.2 Discussion

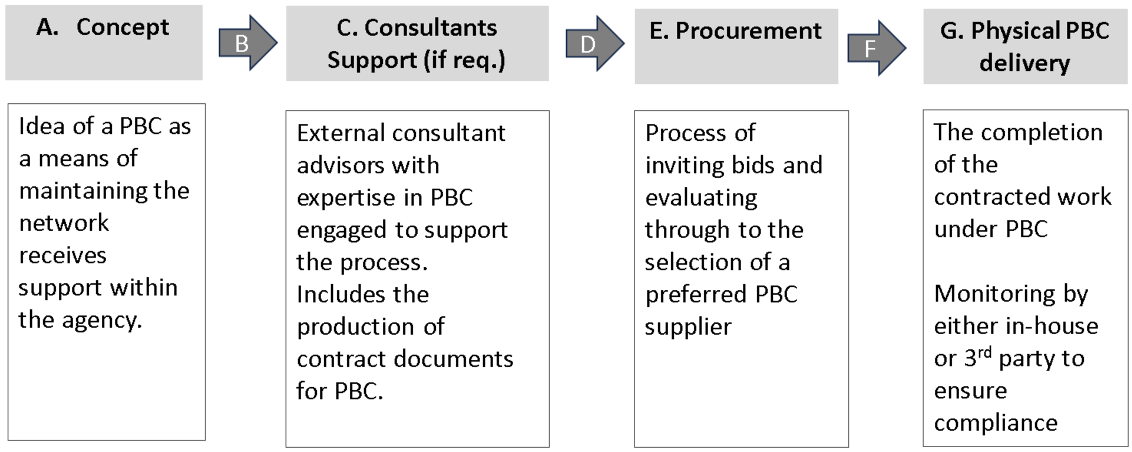
The purpose of this research was to identify the main benefits, challenges, and specific aspects to consider when using PBCs and relate them to California's context.

Caltrans, through the division of maintenance, defines twelve maintenance regions and the state maintenance staff is responsible for maintaining the state highway system, according to the Caltrans Maintenance Manual. Previous experiences from other states could guide Caltrans's initiation in performance-based maintenance contracts. To this end, it is important to highlight (1) what are the main benefits and how they can support the 2019 Report Card California's Infrastructure suggestions, and (2) based on previous experiences, what are the recommendations to start using these types of contracts.

This research found that the three main benefits of PBCs are (1) cost savings, (2) improved work/service quality, and (3) reduction in risk to the transportation agency through the transfer of responsibility to the contractor. Focusing on the cost savings, to accurately obtain the actual cost saving of shifting to PBMCs, it is important to calculate first the life cycle cost of the current contracting approach, which might be the use of in-house workforce or traditional contracting. Then, this cost needs to be compared with the life cycle cost of the PBMC for the same time and scope of work (Shrestha, 2023). Regarding, improved work/service quality, the use of performance specifications allows for innovation. This provides an umbrella for using new materials, design, and technology to address long-term road maintenance.

Challenges identified in this research to implement PBCs include the need for training, and a shift in mindset from traditional contracting forms to PBCs. Opus International Consultants Limited (2012) provided an implementation framework that included seven steps (A to G) that need to be successful to implement PBCs properly (Figure 8).

Figure 8. PBC Implementation Chain Adapted from Opus (2012)



Steps E and G relate to three of the major themes identified in this research: procurement (Step E) and performance indicators/incentives (Step G).

Future research must focus on investigating and testing structured approaches or methodologies that support DOTs in the decision of using (or not) PBCs for their maintenance projects. The application of these approaches in the state of California will provide valuable insight to assess the use of these contracts in road maintenance.

4. Conclusions

PBCs use performance specifications that require specific performance targets but leave the means and methods to achieve those targets open to the contractor. Applying new materials, design, and technology to address long-term road maintenance might be facilitated using PBCs.

This research pursued two objectives. The first was to identify the benefits and challenges of PBCs compared to traditional contracts. Main benefits found include: (1) cost savings, (2) improved work/service quality, and (3) reduction in risk to the transportation agency through the transfer of responsibility to the contractor. The main challenges found relate to (1) the need for training, and a shift in mindset from traditional contracting forms to PBMCs, (2) the need to establish trust between contracting agencies and contractors, and (3) the temptation for contractors to abuse the system.

The second research objective focused on exploring the main aspects of PBCs implementation for road maintenance and relating them to California's road maintenance. Research findings highlighted the procurement, the performance indicators, and the incentives/disincentives clauses as the three major themes to consider in PBCs' implementation. California does not have a history of using performance-based contracts for road maintenance. Results from this research may be the first stepping stone to initiate the decision-making process to use these types of contracts for road maintenance.

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