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16. Abstract

While the literature on public-private partnerships (PPPs) argues that the private sector's life-cycle approach to design and construction results in operational cost efficiencies, empirical support is missing. This study explored that issue by conducting a four-prong investigation. First, a literature review searched for evidence of such efficiencies and methodologies to evaluate them: it found no empirical evidence of superior operations and maintenance (O&M) cost-efficiency in PPPs. Second, a simple methodology to evaluate life-cycle cost-efficiency is proposed, but adequate data and assumptions about O&M costs are needed. Third, since PPP projects in the U.S. are recent and currently subject to routine O&M, indicators to compare those costs were proposed as well. Fourth, a case study compared the routine O&M costs of a PPP to those of a system of traditionally delivered toll roads. The results showed that the PPP was more cost-efficient in operating expenditures (OPEX) per mile (-60%) and per lane-mile (-53%). The traditional system was more cost-efficient in OPEX per vehicle miles travelled (97%), toll transactions (332%), and toll revenue (20%). However, those three indicators depend on traffic volumes, which were overwhelmingly greater on the traditional system. While the case study showed cost-efficiency differences between public and private sectors, additional research is needed to empirically test the hypothesis of the private sector's greater efficiency. Understanding the differences in cost-efficiency between publicly and privately managed roads will help decision-makers to minimize the life-cycle cost of their investments.

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COST-EFFICIENCY OF HIGHWAY OPERATIONS AND MAINTENANCE OF PUBLIC-PRIVATE PARTNERSHIPS

by

Sergio E. Martinez
and
C. Michael Walton

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Southwest Regional University Transportation Center
Center for Transportation Research
The University of Texas at Austin
Austin, TX 78712

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EXECUTIVE SUMMARY

1. INTRODUCTION

Demand for transportation infrastructure in the U.S. increased in the last decades and is forecast to continue growing at a time when a combination of factors undermine the financial capacity of agencies and governments to provide for those needs (*1*). Searching for alternatives to traditional funding mechanisms (*2*), and with pressure to do more with less (*3*), officials at various levels are increasingly considering innovative delivery options (*2*).

Public-private partnerships (PPPs) are gaining popularity as a method to stretch scarce funds (*2*, *4*), and accelerate the provision of backlogged projects by leveraging the expertise and capital of the private sector (*5*). While various contractual arrangements can be classified as PPPs (*6*), one that bundles the design, build, finance, operation, and maintenance aspects is commonly referred to as DBFOM (*7*), and also as a concession if the users pay directly for the service (*8*). DBFOMs are said to offer the greatest potential gains in terms of risk sharing and efficiency because the private entity is in charge of all the phases of the project (*2*); for this reason, they are the focus of this study.

1.1 PPPs for the Delivery of Transportation Infrastructure

Although the U.S. has been slow to embrace PPPs, the momentum is building for their increased application (*9*), as the number of PPPs to deliver transportation infrastructure has increased in the last decade (*10*). One challenge in this area is that while some agencies do not consider PPPs an option, others identify projects as PPPs prematurely with no evaluation of other procurement methods (*11*).

1.2 Evaluation of PPPs

One of the most recognized methodologies to evaluate PPP proposals is a Value for Money (VfM) analysis, a tool used to compare the cost of a PPP project against the hypothetical cost if it was delivered traditionally (*12*). Yet, VfM use is still uncommon and not standardized in the U.S. (*13*), which has recently led to debates about its adequacy (*14*) and calls for further research on evaluation tools for PPP proposals and projects (*11*).

1.3 The Efficiency Claim of PPPs

PPPs are said to offer, among other benefits, increased operational efficiency (reduced costs) resulting from the private sector's life-cycle approach to design and construction within a life-cycle asset management strategy (*1*, *5*, *15*, *16*, *14*, *17, 18*). The rationale is that bundling construction and operation into a single contract allows the internalization of positive externalities between the construction and operational phases—thereby lowering the life-cycle maintenance cost of the facility (*8*)—and that since the concessionaire is paid to build and maintain the facility at contractually specified service levels for long periods of time, it is in the concessionaire's best interest to minimize operations and maintenance (O&M) costs and problems (*19*).

1.4 Problem Statement

Although cost is not the only factor that must be considered when exploring PPPs, it is the most often cited by advocates to support their positions both for and against (*3*). Yet, despite the widespread notion in the literature and among PPP stakeholders that the private sector is more efficient in managing road infrastructure, limited empirical evidence can be found on this subject, (*13*) so there is a need for evidence-based findings to provide clarity on what PPPs can and cannot offer (*10*), especially in terms of efficiency and cost savings.

1.5 Research Goal and Objectives

The goal of this study was to try to assess the notion of whether the private sector is more cost-efficient than the public sector in the management of transportation infrastructure in the U.S. For that, four tasks were carried out. First, a literature review searched for evidence of such efficiencies and for methodologies to evaluate them. Second, from that review a simple methodology is proposed to evaluate life-cycle cost-efficiency. Third, since most PPP projects in the U.S. are recent and currently subject to routine O&M, simple indicators to compare those costs were proposed. Fourth, to illustrate their use, a case study compared the routine O&M costs of a PPP and of a system of traditionally delivered toll roads.

2. PREVIOUS STUDIES

To understand if and how the notion of higher PPP efficiency had been evaluated, the literature review focused on comparisons between PPPs and traditional procurements, performance and efficiency evaluations of PPPs, and on the O&M phase of PPPs.

2.1 Cost and Duration

Studies about PPP performance have focused on their cost and schedule. This is understandable since cost is the most cited element by both PPP supporters and critics but also because in traditional procurement, cost and time overruns are common (*8*). Such studies concentrate in the design and construction phases because the majority of projects have recently started operations, but also because of the difficulties in obtaining performance data about the O&M phase. Two broad types of comparisons were found in the literature: comparisons of total construction cost, and of cost and schedule growth.

2.1.1 Total Cost

Based on a review of economic theory suggesting that the ex-ante construction cost of a PPP should be higher than in traditional procurement, Blanc-Brude et al. compared the cost of constructing road projects in Europe under both DBFOMs and traditional procurement. The study examined whether and by how much construction costs differed (*8*). Focusing only on the construction costs, they evaluated over 200 road projects financed by the European Investment Bank between 1990 and 2005.

The results showed that on average, the PPP projects had 24% higher ex-ante construction costs than the projects delivered traditionally. The authors suggested the difference could be the result of higher investments in the design/construction phases that sought to reduce costs during the projects operations, and also of the risk premium charged by concessionaires for assuming the transferred risks. They acknowledged that because their analysis focused only on the construction costs, the results did not allow them to draw normative conclusions about the economic desirability of PPPs as a procurement method (*5*).

2.1.2 Cost and Schedule Change

To evaluate whether transportation infrastructure projects performed as promised in terms of costs, Flyvbjerg et al. (*20*) analyzed 258 projects in 20 countries, showing with overwhelming statistical significance that the costs of transportation infrastructure projects (of all types) were highly uncertain: nine out of ten projects suffered cost escalation, with road projects experiencing average cost escalation of 20%. They concluded that the cost estimates used in public debates and decision-making for transport infrastructure development were highly, systematically, and significantly misleading.

Furthermore, they argued that such misleading cost estimates generated risks that were typically ignored or underplayed in decision-making. The risk of cost overruns is, along with the risk of schedule delays, one of the main risks typically transferred to the private partner in a PPP. For that reason, the review moved on to explore PPPs.

2.1.3 What about PPPs?

Results from many studies (*21, 19, 22, 23, 24*) suggest PPPs are superior in terms of cost and schedule control than traditional procurement. However, as Hodge and Greve pointed out, statistically solid evidence to support such notion is weak and at times controversial (*21*).

Raisbeck et al. echoed critiques made by researchers at University College London (*25*) about the then-existing research on PPP performance, which was suggested to be biased in favor of PPPs. Addressing most of those identified issues, and given concerns about widespread optimism bias and lack of appropriate data for capital projects decision-making, they designed a rigorous methodological approach to compare the duration and cost of Australian PPPs and projects delivered traditionally (*22*).

The results showed superior cost-efficiency of PPPs with an average of 2.4% cost overruns between contractual commitment and final outcome, versus 13.8% for traditional projects. Time overruns were 2.5% for PPPs and 2.3% for traditional projects, which the authors characterized as exceptional for PPPs, given they are subject to additional scrutiny, and that traditional projects were said to have a head start since their general specifications are known at the project's announcement.

2.1.4 And in the U.S.?

European and Australian markets are so different that their findings cannot be directly transferable to North America. Therefore, Chasey et al. performed what they claimed is the first comprehensive study comparing PPPs against traditionally delivered transportation projects in North America (*15*). Traditional projects were defined as any procurement method other than DBFOM.

Results from a literature review of cost and schedule growth in Design-Bid-Build (DBB) and Design-Build (DB) highway projects were used as a benchmark to be compared against a group of PPP highway projects. The 12 PPP projects compared were highway and bridge projects constructed between 1990 and 2010, delivered as DBFOMs, with costs between \$90M and \$1.1B, located in the U.S. or Canada.

The DBFOM projects performed better in terms of cost change (0.81%) than the DBs (4% and 1.49%), and much better than the DBBs (12.71%). From this, they concluded that the cost control of DFOM projects may be attributable to the DB portion more than to the FOM portion. In terms of schedule, the PPPs showed average schedule change of -0.3%, compared to -11% and 11.04% in DBs and 4.34% in DBBs.

The authors posed doubts about what they referred to as the conventional wisdom that the construction phase is the riskiest. In terms of schedule change, they justified the good performance of the PPPs as resulting from the concessionaire's incentive to begin operations quickly to start recovering their investment. They also recognized that, as positive as the statistics were for cost and schedule control, those are only two aspects of a PPP. The authors recommended research on other factors that could result in additional efficiencies—they called specifically for more investigation of the O&M, which they related to the private sector's incentive to produce a better quality project.

The literature review showed that, as acknowledged by Blanc-Brude et al., *"the comparison of cost* [and schedule] *overruns in PPPs and traditional public procurement is arguably a comparison of apples and oranges"* because there is less incentive to provide accurate construction budgets in traditional procurement since the public sector bears those risks (*8*). Also, since most PPP projects are still in construction or in their early years of operation, most studies have focused on the design and construction phases. Yet, for a PPP to offer a greater VFM to the owner and its users, there must be other sources of value. Therefore, the review of literature explored other types of PPP evaluations.

2.2 Efficiency of PPPs

Reviewing literature about PPP efficiency did not yield nearly as many results. Two relevant studies are discussed next.

To evaluate long-term leasing of toll roads, Zhang et al. proposed a probabilistic framework focusing on economic efficiency and the protection of the public interest (*1*). In regard to economic efficiency, they used net present values (NPV) to compare two scenarios: 1) the public agency leases the toll road to a private concessionaire and 2) the agency continues to operate the toll road.

In the privatization scenario the public agency receives an up-front lease payment with no revenue or risk sharing. Since the analysis was done from the point of view of the agency, this payment was the only value evaluated, as the agency would relinquish control of the facility.

In the in-house scenario, the NPV of toll revenues were calculated as shown:

$$R(\varepsilon_R) = \sum_{i=1}^{n}[\frac{v_i(\varepsilon_v) * t_i(\varepsilon_t)}{(1 + r_i(\varepsilon_r))^i} + \frac{or_i(\varepsilon_{or})}{(1 + r_i(\varepsilon_r))^i}]$$

where:
R = present worth of total revenues in lease period,
v_i = traffic volume in year i,
t_i = average toll for unit traffic in year i,
or $_i$ ($\varepsilon_{\mathrm{or}}$) = other revenues excluding toll revenue in year i,
n = total years of lease period,
r_i = discount rate in year i, and
ε_R, ε_v, ε_t, $\varepsilon_{\mathrm{or}}$, and ε_r = uncertainties related to toll revenue, traffic volume growth, toll rate growth, other revenues, and discount rate.

And the NPV of the costs were calculated thusly:

$$C(\varepsilon_C) = \sum_{i=1}^{n}\frac{o_i(\varepsilon_o) * p_i(\varepsilon_p) + oc_i(\varepsilon_{oc})}{(1 + r_i(\varepsilon_r))^i}$$

where:
C = present worth of total costs in entire lease period,
o_i = operating costs in year i,
p_i = preservation costs in year i,
oc_i = other costs in year i, and
ε_o, ε_p, *and* ε_{oc} = uncertainties related to operating costs, preservation costs, and other costs.

Comparing the NPVs of the two scenarios, the authors wondered about the rationale for privatization. They suggested two answers: that a public agency would not increase toll rates as frequently or as high as would a concessionaire, resulting in fewer revenues, and that the private sector tends to exhibit superior operating efficiencies, implying reduced costs. Such claimed efficiencies by the private sector are what concern this study.

A case study of the Indiana I-90 toll road lease was done to illustrate the framework and an NPV analysis (based on a Monte Carlo simulation) accounted for the input's uncertainties. The results indicated that from a purely financial perspective, the public agency made the right decision by leasing the toll road.

A study by Daito and Gifford evaluated the efficiency of PPPs in a different manner. They argued that previous studies have used statistical analyses but that in the U.S. the number of completed PPPs is not large enough to allow rigorous statistical analysis. Further, those analyses require *a priori* functional forms that make them difficult (*13*). Therefore, Daito and Gifford evaluated the efficiency of PPP delivery—measured as cost savings—using frontier analysis with Data Envelopment Analysis (DEA). DEA is a non-parametric approach to conduct efficiency analysis of multiple inputs and/or outputs that imposes minimum assumptions and does not require the specification of an *a priori* functional form.

They used tolled and non-tolled road capacity expansion projects delivered as DB, design-build-finance (DBF), Design-Build-Maintain (DBM), or DBFOM contracts as Decision Making Units (DMUs), and project delivery as the production of those DMUs. They modeled the projects' total cost at the financial close as the input, and lane-mileage, number of bridges, and number of interchanges as outputs. Their model evaluated 37 projects in the U.S., although they acknowledged that these projects are complex and their output should include more variables. Because unusual results arose, they hypothesized that more sophisticated variable specifications were needed to better capture project outputs.

For future research, they suggested incorporating environmental and socio-economic factors due to the likelihood that these factors would affect DMU efficiency levels and cost structures. They also recognized the challenges in empirically evaluating whether the cost-savings presumption under which PPPs were originally proposed holds true in actual projects.

2.3 Performance of PPPs

The long-term nature of a PPP gives rise to project components and risks not typically found on traditional projects, some of which can change over the life of the project. Consequently, evaluating a PPP is difficult and the use of time and cost measurements do not reflect their complexity, according to Liu et al. (*16*). They proposed a conceptual dynamic life-cycle performance measurement framework for PPP infrastructure projects that can deal with the complexities arising from having multiple stakeholders; the framework used the *performance prism* (stakeholder satisfaction; strategies; processes; capabilities; and stakeholder contribution) based on the arguments of Neely et al. (*24*).

Since typical evaluations of PPPs are either ex ante or ex post, Liu et al. suggested two additional evaluation nodes so that project managers can measure project performance in each phase, providing them real-time performance review capabilities to identify how well their resources were utilized in the previous phase, what should be done to improve, and what should be the focus in the subsequent phase.

Overall, Liu et al.'s proposed evaluation framework is said to help capture some of the dynamism of a PPP project. Yet, while the framework can help PPP project managers, its use would not be appropriate for comparing them to traditionally developed projects because the latter are, by nature, fragmented into pieces for which different parties are responsible, each with unique interests.

2.4 Operations and Maintenance in PPPs

Evaluating the performance of a PPP during the O&M phase could be done by benchmarking actual performance data against the original contract, the public sector comparator, similar facilities procured traditionally, or private competitors of the private partner (*26*). Two of those methods have been documented in this study to evaluate the design and construction phases: benchmarking against conventional procurement and against the original contract. However, their use for the evaluation of the O&M phase is problematic—most PPPs in the U.S. are recent, so few projects have been in operation long enough to have generated adequate performance data for comparison.

There is also the issue of data confidentiality and the difficulty of having a private entity share their proprietary performance data. Additionally, since the O&M phase in a PPP is usually long, changes in the requirements can be expected, complicating benchmarking against the original contact (*26*). Perhaps for these reasons, the literature review did not find adequate empirical evaluations of the O&M phase of PPPs in the road sector.

In the UK, private finance initiative (PFI) projects are the equivalent of PPPs. In 2002 Akbiyikli and Eaton (*17*) cited a report from the UK's Private Finance Panel arguing that a PFI is designed not to borrow money from the private sector but to transfer risk to the private sector. Coupled with efficiencies in management, a PFI's resulting benefits would outweigh the higher costs of private funding, resulting in greater value to taxpayers. This is the same argument that resonates with PPP supporters in other countries.

Akbiyikli and Eaton examined the then-current O&M management practices in PFI road projects in the UK. Based on two DBFOM empirical case studies, they proposed a conceptual framework for O&M management, identifying physical and functional performance as the critical O&M criteria. Secondary parameters were innovation, effectiveness, efficiency, and certainty, all of which are to be measured in terms of time, cost, and quality (*17*).

Efficiency, the focus of this study, was defined as the minimization of resources required to deliver the agreed outputs at appropriate quality levels. From their analysis of the two case studies, Akbiyikli and Eaton concluded that the functional and performance requirements have to be considered at the beginning of the project, and that the management of the O&M has to focus on the delivery of the services by minimizing the O&M expenses while maximizing the quality of those services.

Their paper was strictly theoretical and the framework seemed unpractical at first, as there were no indications of how it was to be used. However, in a subsequent study Akbiyikli applied the framework to a PFI road project on the eastern coast of Scotland to examine whether the performance in the operations phase was complying with the output specifications to the satisfaction of the users (*19*).

Based on a survey and a semi-structured interview, Akbiyikli examined the first four years of the O&M phase of the A92 project and, according to the author, the results showed that the project satisfied the strategic objectives, efficiency, service delivery outcomes, quality, and effectiveness. He concluded that the concession was performing very well and to the satisfaction of all stakeholders.

Akbiyikli's paper illustrated a different type of evaluation as it focused on qualitatively assessing the performance of the project from the point of view of the users. While it was based on a single project that does not allow generalizations, it provided a very good indication of the subject project performance (*19*). Although the results were not compared against a traditionally procured project, such a comparison would only require conducting similar surveys to obtain comparable data.

3. METHODOLOGY TO COMPARE THE LIFE-CYCLE EFFICIENCY OF PPPS AND TRADITIONALLY PROCURED PROJECTS

The literature review demonstrated that comparisons of the benefits and costs of PPPs vis-à-vis traditional procurement are difficult and require comprehensive evaluation frameworks. Moreover, it showed that empirically determining whether PPPs result in more efficient life-cycle management than traditional procurement is difficult: an individual project cannot be assessed until it has completed its contract cycle, and a program cannot be assessed until a sufficient number of projects are completed.

3.1 Proposed Methodology

Of the evaluation methodologies reviewed, we recommend the one proposed by Zhang et al. to compare the life-cycle economic efficiency of toll roads between the public and private sectors because of the methodology's life-cycle approach, simplicity, and capability to evaluate uncertainties of the inputs. Besides, the framework can be used in a scenario approach: a DBFOM concession vs. a publicly developed and managed project.

Zhang's paper evaluated the leasing of a toll road against the alternative of continued in-house management by a public entity. To be able to compare a DBFOM concession, two changes would be needed. First, the PPP scenario should evaluate the toll revenues and costs over the life of the concession; thus, the NPV of this scenario would result from using the proposed equations. The second change would be in the estimation of the annual operating costs. In the Zhang study, the PPP comprised only an up-front lease payment so no estimation of costs was needed. For their public management scenario, annual operating costs were estimated by fitting a statistical function to the historic costs since the facility had been in operation by the same entity. Because a DBFOM is a greenfield project, no historic operating costs exist, so that method is not appropriate.

The easiest way to estimate those costs would be to fit historic data from similar facilities in the project's vicinity that are managed by the same entity. However, the literature on PPPs argues strongly that the private sector is more efficient than the public sector; if true, it is unlikely a private concessionaire would incur similar costs as a public entity.

Since most PPPs in the U.S. have recently started operations, they are currently subject to routine O&M activities. To compare the costs of the private and public sectors in the management of toll roadways, a set of indicators are proposed and used in a case study analysis in the next section.

3.2 Factors to Consider

For a comparison to be effective and fair, the compared facilities should have relatively similar characteristics; if not, efforts should be made to try to "level the field." In the case of large road infrastructure projects such as toll roads, attaining a level playing field is difficult since all such projects are unique. Thus, to perform a detailed comprehensive cost performance comparison between different roadways, it is important to consider the differences in type of highway, project type (greenfield vs. brownfield), location, traffic volume and composition, pavement type, frontage roads, bridges, number of toll gantries/ramps, O&M decision-making approach (dedicated vs. network), emergency response roles, intelligent transportation systems (ITS), disaster evacuation, etc.

4. CASE STUDY COMPARISON OF ROUTINE OPERATIONS AND MAINTENANCE COSTS IN TOLL ROADS

The purpose of this case study was assess any differences in the routine O&M costs of a group of toll roadways in the U.S. to evaluate whether the private sector is more efficient in roadway management, as argued in the PPP literature. One aspect common to these types of projects is the need to maintain certain information confidentiality, primarily for two reasons. First, most concessions and some publicly owned toll roads are funded by private investors, and second, public access to financial and management strategies could expose the entity to unwarranted exposure and reduced competitive advantage. Therefore, to protect the confidentiality of the data presented, this is a "blind" case study, meaning that the names, locations, and the owners/managers of the facilities are not disclosed.

4.1 Compared Facilities

One toll road was developed under a DBFOM, so it was designed and built by a private concessionaire, the same that now manages it. This facility will be referred to as "the concession," and it will illustrate the characteristics of a privately delivered and managed roadway.

To contrast the PPP model, a group of toll roads located in the vicinity of the concession were selected. These facilities were developed under traditional procurement models—either as DBB or DB contracts—and they all are under the management of a State Department of

Transportation (DOT). They were selected because they are close to the concession, owned by the same DOT that arranged the concession, and collectively managed as a system. They will be referred to as "the system."

4.2 Study Period

The study period is one year; however, the DOT records expenditures on a fiscal-year basis while the concessionaire records expenditures on a calendar-year basis. Consideration was given to matching their data but it was decided to maintain their original formats. Thus, the system data corresponds to fiscal year 2013, while the concession's data corresponds to the 2013 calendar year.

4.3 Characteristics of the Facilities

- **Type:** All the roadways are toll highways.
- **Length:**
    - **Centerline Miles:** The total centerline miles of the mainline lanes in the concession are approximately 40, and in the system approximately 73.
    - **Lane-miles:** The concession has approximately 160 lane-miles and the system about 345.
- **Annual Average Daily Traffic (AADT):** During calendar year 2013, the concession served approximately 5,564 vehicles per day. In fiscal year 2013, the system served approximately 130,820 vehicles each day.
- **Annual Vehicle Miles Travelled (VMT):** Because no actual VMT data was obtained, based on the AADT and the centerline miles and assuming each vehicle traveled the entire length of the road, estimated VMT in the concession were approximately 81,157,679, and 735,970,669 in the system.
- **Toll Transactions:** The number of toll transactions in the concession was about 5,153,558 with approximately 102,507,240 in the system.
- **Toll Revenue:** The total amount of toll revenue collected in the concession was an estimated $18,854,588; in the system approximately $103,984,500 was collected.

Due to the lack of readily available information about certain characteristics of the system, not all of the desired indicators could be used.

4.4 Operations and Maintenance Costs

This section summarizes the annual operating expenses (OPEX) incurred by both the DOT and the concessionaire while operating and maintaining their respective facilities.

4.4.1 Cost Differentiation

Differentiating between direct and indirect costs is important for an appropriate cost analysis. Direct costs, are those that can be identified specifically with a particular cost objective, while indirect costs, also known as overhead, are those incurred for a purpose benefiting more than one cost objective and that are not readily assignable to the cost objectives specifically benefitted (*3*).

4.4.2 Availability of Data

Since access to detailed technical and cost information was needed about the facilities, data requests were sent to both the DOT and the concessionaire. It should be recognized that despite its private nature, the concessionaire was open and responsive to all data requests. On the other hand, while some of DOT staff members were quite helpful, the DOT's legal department would not provide the detailed cost information requested, arguing concerns about potentially confidential information being made public, as the system is funded by private investors. Therefore, no financial information was released other than publicly available information and no clarifications about published information were provided.

The main consequences from this non-disclosure of information were the impossibility of clearly identifying which of the system's costs were direct or indirect and how many DOT employees supported the management of the system. For this reason, the classification of the system's costs presented in this study is the result of interpreting publicly available reports. The concessionaire did provide its own cost classification.

Lacking the DOT's input about the nature of its costs, the more unbiased way to compare the system and the concessionaire costs was to use the same criteria to classify them all. In this case, that meant using the concessionaire's classification as a guide. However, the level of detail of the system's published information made that process difficult. Consequently, it was decided to create two scenarios for the system's data in an attempt to emulate the categorization principle used by the concessionaire, but with different levels of rigor.

- **Scenario 1:** Only the "Repairs and Maintenance" category was considered direct. While that might seem "extreme," this is the only category that can be easily related to the O&M of the facility.
- **Scenario 2:** In addition to "Repairs and Maintenance," "Contracted Services" was classified as direct because the system has contracted out its maintenance and the toll collection operations. "Salaries" was also considered direct because the supervision of those contracts and the management of the system are performed by DOT staff.

Overall, the system had operating expenditures of $47.3 million, of which 34.29% were assumed to be direct costs and 65.71% indirect costs under scenario 1. In scenario 2, 64.19% were assumed to be direct costs and 35.81% indirect. The concession spent $10.3 million in total OPEX with 56.81% in direct costs and 43.19% in indirect costs, as identified by the concessionaire. See Figure ES.1.

4.5 Results

The comparison was done in two ways: for the total OPEX and for the direct and indirect OPEX under the two scenarios. The system was used as the baseline against which the concession's costs were compared; therefore, the values shown in the column labeled "difference" in Table ES.1 indicate the percentage difference that the concessionaire spent compared to what the DOT spent.

As Table ES.1 and Figure ES.2 indicate, the comparison showed that the concessionaire was more cost-efficient in terms of total OPEX as well as assumed direct and indirect OPEX per mile and per lane-mile. The DOT was more cost-efficient for all types of OPEX (total and assumed direct and indirect) in relation to the number of VMT and the number of toll transactions. However, those two metrics depend on the amount of traffic volume on the facilities, which during the study period was overwhelmingly larger on the system, helping it to spread its costs over a much larger base.

Special attention should be given to the operating expense ratio (OPEX per toll revenue) because of its distinct behavior in this study. This ratio indicated that the system was more efficient in terms of total OPEX, and though this indicator also depends on traffic volume, which favors the system, when direct costs were analyzed under the conservative scenario 2, the concessionaire spent only about 6% more than the DOT.

This is important because direct costs are those directly related to the actual O&M work and the system has contracted out its maintenance to a private contractor, while the concessionaire uses its own employees. Therefore, this finding could indicate that the concessionaire is more efficient in the performance of the O&M activities than the DOT maintenance contractor.

While there is no data to support it, one hypothesis could be that, as suggested by the literature, the concessionaire made decisions during the design/construction phases to minimize operation costs. Another reason could be that since the contractor was not involved in the design/construction of the system's roads, its fees include a risk premium for maintaining facilities for which it cannot vouch.

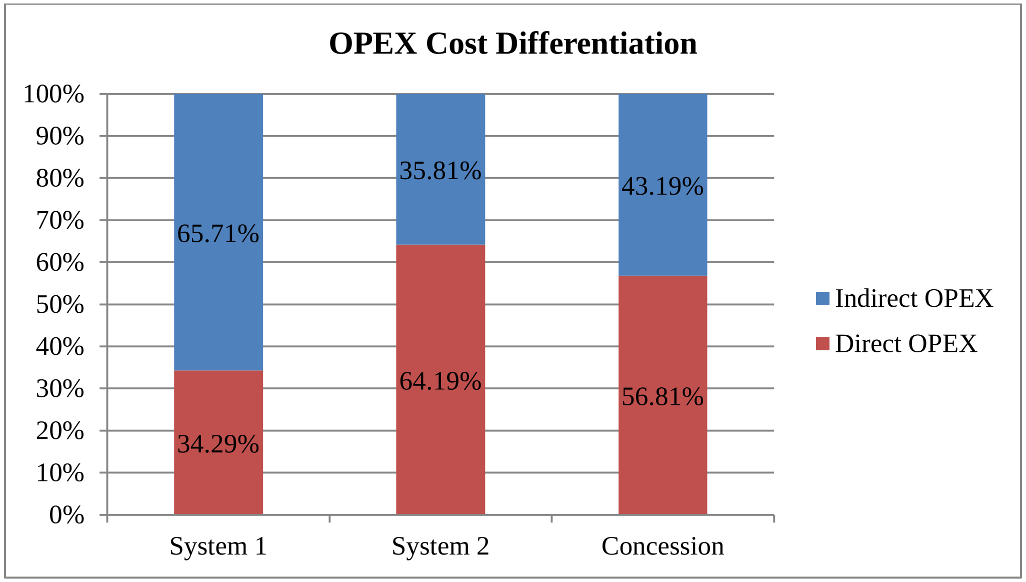
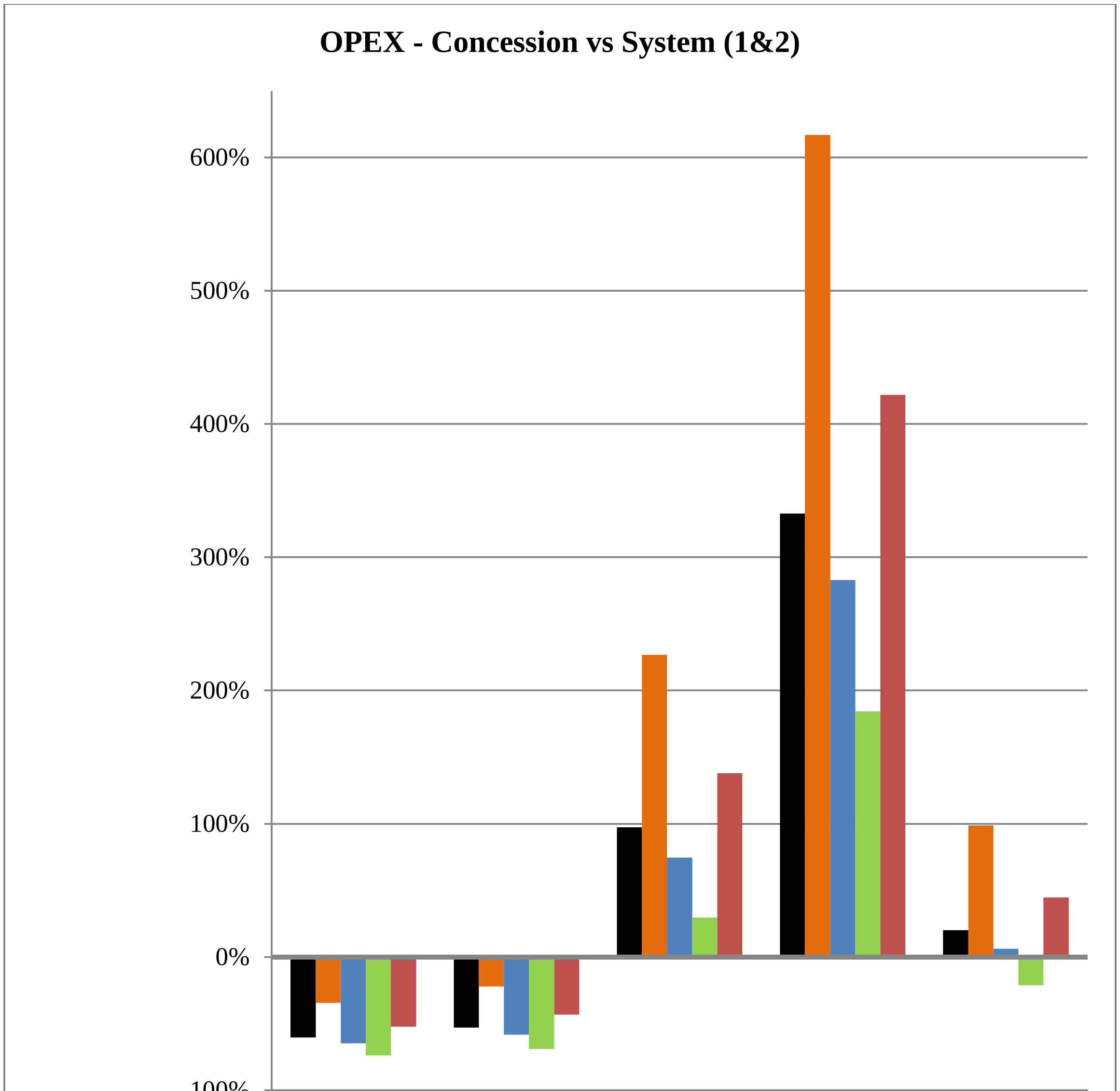


Figure ES.1. OPEX Cost Differentiation for the System and the Concession.

Table ES.1. Comparison of OPEX Concession vs. System (Baseline).

Total OPEX					Direct OPEX (D.O.) and Indirect OPEX (I.O.)									
Indicator	Unit	Concession	System	Difference (%)	Concession		System							
							Scenario 1				Scenario 2			
					D.O.	I.O.	D.O.	Diff.	I.O.	Diff.	D.O.	Diff.	I.O.	Diff.
OPEX/Mile	($/Mile)	257,929	650,821	**-60.37**	146,530	111,399	223,179	**-34.34**	427,643	**-73.95%**	417,732	**-64.92%**	233,090	**-52.21%**
OPEX/Lane-Mile	($/Lane-Mile)	64,482	137,213	**-53.01**	36,632	27,850	47,053	**-22.15**	90,160	**-69.11%**	88,071	**-58.41%**	49,143	**-43.33%**
OPEX/VMT	(¢/VMT)	12.70	6.44	**97.30**	7.22	5.49	2.21	**226.85**	4.23	**29.68%**	4.13	**74.63%**	2.31	**137.92%**
OPEX/Transaction	($/Trans.)	2.00	0.46	**332.75**	1.14	0.86	0.16	**616.92**	0.30	**184.44%**	0.30	**283.02%**	0.17	**421.86%**
OPEX/Toll Revenue	(%)	54.67%	45.56%	**19.99**	31.06%	23.61%	15.62%	**98.78**	29.94%	**-21.13%**	29.25%	**6.20%**	16.32%	**44.70%**



	OPEX / Mile	OPEX / Lane-Mile	OPEX / VMT	OPEX /Transaction	OPEX / Toll Revenue
Total OPEX	-60.37%	-53.01%	97.30%	332.75%	19.99%
Direct OPEX (1)	-34.34%	-22.15%	226.85%	616.92%	98.78%
Direct OPEX (2)	-64.92%	-58.41%	74.63%	283.02%	6.20%
Indirect OPEX (1)	-73.95%	-69.11%	29.68%	184.44%	-21.13%
Indirect OPEX (2)	-52.21%	-43.33%	137.92%	421.86%	44.70%

Figure ES.2. Graphical Comparison of all Scenarios.

5. CONCLUSIONS

The literature on PPPs argues extensively that the private sector is more efficient than the public sector in operating road infrastructure, identifying this efficiency as a benefit of PPPs. Yet, those studies don't provide empirical support. This study conducted a four-prong investigation. First, it searched the literature for evidence of those efficiencies and methods to evaluate them. Second, it proposed a simple way to compare life-cycle cost efficiency in toll roads. The results showed the following:

1. The literature review found no empirical evidence for superior cost-efficiency of PPP concessionaires in the O&M phase.
2. The majority of studies comparing PPPs against traditional delivery projects focused on design and construction cost and schedule overruns, some of which used not-so-rigorous evaluations.
3. The studies that assessed performance and/or efficiency during a project's life cycle were at times highly theoretical and their methods are not likely being employed outside of academia.
4. The NPV-based probabilistic framework proposed by Zhang et al. could be used, in a scenario analysis, to evaluate the life-cycle efficiency of DBFOM projects against traditionally developed alternatives. The framework is useful due to its simplicity, life-cycle approach, and ability to evaluate uncertainty. Yet, in Zhang's study, a methodology to estimate the annual operating costs for both the public and private scenarios is not available for the evaluation of greenfield projects.

Third, to empirically test the assumption about the private sector's greater efficiency, simple comparison indicators were proposed. Fourth, to illustrate the use of these indicators, a limited-scope case study was performed to compare the routine O&M expenditures of a concession against a system of publicly managed toll roads, yielding these results:

1. There were significant differences between the privately and the publicly managed facilities in terms of the cost-efficiency of the routine O&M. Specifically:
    a. The concession was more cost-efficient in terms of OPEX per mile and per lane-mile.
    b. The system was more cost-efficient than the concession in relation to VMT, the number of toll transactions, and the toll revenue collected. Yet, those indicators depend on the traffic volume, which during the study period was overwhelmingly greater on the system, helping it to spread costs over a much larger base.
2. The difference in managing a network of facilities (as public agencies do) versus a single facility (as concessionaires do) is most evident in terms of coordination

between sections within the entities. Some DOT staff lacked a basic understanding of the system's management, financial, and performance characteristics; this was not an issue with the concessionaire's staff.

6. LIMITATIONS

This study's main limitation was the non-disclosure of the system's detailed financial data. Citing confidentiality concerns, the DOT's legal department forbade any release or clarification of financial information. This created the need to assume what costs were direct or indirect and eliminated the possibility of assessing efficiency per number of employees, among other things.

Another limitation of the case study was the inability to use more comparison indicators due to the lack of readily available information about some of the system's physical characteristics. This further limited the comprehensiveness of the case study's evaluation.

7. FUTURE RESEARCH

The case study showed differences in cost-efficiency of routine O&M activities in toll roads between the public and private sectors, but more research is needed to empirically test the hypothesis of greater efficiency in the private sector. While it would be interesting if other methodologies were proposed, Zhang et al.'s proposed framework can be used as it is simple and easy to understand by decision-makers and stakeholders, an important consideration that is sometimes forgotten by academics. However, adequate data and assumptions about O&M costs are needed to produce adequate results. For that, more comprehensive case studies than this one should be performed, using either the proposed or similar indicators, to obtain sufficiently detailed empirical data. The factors discussed as necessary to make the comparisons adequate should be evaluated.

The results will help public sector decision-makers to decide whether to procure a project as a PPP, and aid concessionaires wanting to evaluate themselves against public agencies or when entering new markets. Ultimately, those results can help to either prove or disprove the still unsupported claims found in the literature today.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Demand for transportation infrastructure has been increasing in the last decades in the U.S. and it is forecast to continue growing. This happens at a time when a combination of factors undermines the financial capacity of transportation agencies and governments to provide for those needs (*1*): investment in transportation infrastructure is inadequate (*2*) as transportation agencies face increasing revenue shortfalls to maintain and expand their transportation systems (*3*). Consequently, funding and the delivery of transportation infrastructure in the U.S. are changing (*4*).

In the search for alternatives to the decreasing purchasing power of traditional gas-tax-based funding mechanisms (*3*), and with increasing pressure to do more with less (*2*), officials at both state and local levels are increasingly considering innovative delivery options (*3*), including a more prominent role of the private sector. But private involvement in infrastructure delivery is not new (*5*): the responsibility for planning, building, and maintaining roadways has swung back and forth between the private sector and government agencies (*6*). In fact there is a continuum of delivery mechanisms that range from full public delivery to full privatization (*7*).

One approach that has gained popularity is the incorporation of private sector investment for infrastructure provision, under the umbrella of what are known as public-private partnerships (PPPs). Although PPPs have been used for centuries as a tool for governments to deliver public infrastructure (*8*), they have been receiving a great deal of attention lately in the U.S. as a method to stretch scarce funds (*3*, *9*), and accelerate the provision of back-logged projects by leveraging the expertise and capital of the private sector (*4*).

1.1.1 What are PPPs?

Public-private partnerships or PPPs can be loosely defined as cooperative institutional arrangements between the public and private sectors (*10*). Because of their broad definition, there are several contractual arrangements that can be classified as PPPs (*11*). These definitions vary by country (*12*), causing disagreements about what a PPP actually is (*10*).

For example, in the U.S. various procurement methods that involve the private sector have been used to deliver transportation infrastructure such as design-build (DB), design-build-finance (DBF), design-build-operate-maintain (DBOM), and other hybrid arrangements. Under the broad definition mentioned above, all of those procurement methods could be characterized as PPPs even though they differ in terms of how they split financing and operational functions and risks between the public and private partners (*3*).

A contractual arrangement that bundles the design, construction, finance, operations, and maintenance aspects of a legally and economically self-contained project into a long-term contract between a public entity and a standalone private firm—known as a special purpose vehicle (SPV)—is commonly referred to as a DBFOM (*13*); if the users pay directly for the service, these arrangements are also referred to as concessions (*5*). These types of PPP arrangements have been used extensively around the world to build roads, bridges, and tunnels (*13*) and are said to offer the largest potential gains in terms of risk sharing and efficiency because the private entity is in charge of all the phases of the project (*3*). For this reason, a DBFOM is the PPP model that concerns this study; any subsequent reference to PPPs refers to this specific model.

1.1.2 PPPs for the Delivery of Transportation Infrastructure

Unlike other developed countries, such as Canada, the UK, and Australia, the U.S. has been slow to embrace PPPs; however, the momentum seems to be building for their increased application (*8*) as the number of PPPs used to deliver transportation infrastructure in the U.S. has increased in the last decade (*14*). Currently, there are 30 proposals in the pipeline for DBFOM PPPs, with the majority proposed in the last 3 years, including projects in 10 states that are trying PPPs for the first time: Alaska, Arizona, the District of Columbia, Louisiana, Maryland, Mississippi, North Carolina, Ohio, Oregon, and Pennsylvania (*3*).

One challenge that arises with the trend of increasing PPP usage is that, while some agencies do not consider PPPs as an option, others prematurely identify a project as a PPP with no evaluation of how such a project would fare under other procurement methods (*15*). This lack of evaluation is problematic, since major decisions about transportation infrastructure investments should be the result of appropriate evaluations of the life-cycle benefits and trade-offs of various delivery methods.

1.1.3 Evaluation of PPPs

One of the most recognized methodologies used to perform these comparisons is a Value for Money (VfM) analysis. A VfM analysis, which has been described as “the optimal combination” of full life-cycle cost and the quality of the project being provided (*16*), is a tool used to compare the cost of a PPP project against the hypothetical traditional delivery cost (*17*), also known as a public sector comparator.

VfM is an established framework in the UK, Australia, Canada, and the Netherlands, but its use is still uncommon and not standardized in the U.S. (*18*). In fact, there are debates about its adequacy (*19*) and calls for further research on evaluation tools for PPP proposals and projects (*15*).

1.1.4 The Efficiency Claim of PPPs

PPPs for the delivery of transportation infrastructure are said to offer faster project delivery, freeing up of public funds, and among other benefits, increased efficiency through the private sector’s life-cycle approach to design and construction (*1*, *4*, *12*, *20*). In a recent survey, transportation PPP stakeholders in the U.S. were asked about the benefits that the private sector could bring to transportation infrastructure provision and the most frequent answer was the possibility to expedite the delivery of the projects, followed by life-cycle cost planning, which was said to result in long-term efficiencies (*14*).

Respondents felt such efficiencies would arise from a single entity administering the integrated planning of a project's entire life cycle—in this case, a private concessionaire (*14*, *19*). By "efficiencies," they meant reduced costs in the operation of the facility as the result of design, construction, and operation practices focused on life-cycle asset management under a performance-based contract (*6*, *19*, *21*).

The rationale is that the bundling of the facility's construction and operation into a single contract allows the internalization of any positive externalities that may exist between the construction and operational phases, thereby lowering the life-cycle maintenance cost of the facility (*5*). Further, it is in the concessionaire's best interest to minimize operations and maintenance (O&M) costs and problems (*15, 22*) because 1) a PPP concessionaire is paid a fixed amount of money to build and maintain the facility at contractually specified service levels for long periods of time, and 2) the O&M phase is the longest on a PPP concession and the most important, as is when the service delivery and payment conditions are created (*20*).

1.2 PROBLEM STATEMENT

Although cost is not the only factor that must be considered when exploring alternative delivery methods such as PPPs, it is the one most often cited by advocates, both for and against, to support their positions (*2*). According to Papajohn et al., the primary reasons for which states enter into PPP projects is for financial reasons (57%), followed by the prospect of time and cost savings (21%) (*15*).

Yet, despite the widespread notion in the literature and among PPP stakeholders that the private sector is more efficient in managing road infrastructure than the public sector, limited empirical evidence support can be found in the literature to demonstrate such efficiencies (*18*). Because current debates over PPPs are characterized by loud criticism or gushing praise rather than evidence-based learning and synthesis (*10*), there is a need for evidence-based findings to provide clarity on what PPPs can and cannot offer (*14*), especially in terms of efficiency and cost savings.

1.3 RESEARCH GOAL AND OBJECTIVES

The goal of this study is to assess the notion of whether the private sector is more cost-efficient than the public sector in the management of transportation infrastructure in the U.S. At present, both the number and tenure of PPP road facilities in the U.S. are limited, but are forecast to increase. As the number of PPPs in operation increases and the facilities in operation start aging—with the consequent need for larger and more frequent maintenance interventions—additional data will be available to perform more comprehensive comparisons on the efficiency differences, if any, between the public and private sectors. Such comparisons should become key elements of future feasibility evaluations of PPP proposals.

To aid in the development of such evaluations, three objectives were defined. The first objective was to conduct a literature review searching for empirical evidence of such efficiencies and a methodology to evaluate the life-cycle cost efficiency differences between the public and private sectors. Since most PPP projects in the U.S. have only recently started operations and are currently subject to routine O&M activities, a second objective was to propose a set of simple indicators to compare the routine O&M costs of roadway facilities. To illustrate their use, a third objective was to conduct a case study comparing the cost of routine O&M activities of a group of toll highways in the U.S. (a PPP concession, and a system of roads developed and managed by a public agency), to determine if the PPP concessionaire manages its road infrastructure more efficiently than the public sector does.

A better understanding of any cost-efficiency differences between publicly and privately managed toll roads will provide decision-makers a clearer indication of how the selection of a delivery method could affect the overall life-cycle cost of their investments.

1.4 REPORT ORGANIZATION

This chapter introduced the concept of using PPPs for the delivery of transportation infrastructure and the notion that PPPs impart efficiencies in the management of that infrastructure. Chapter 2 presents a literature review in which the research team sought empirical evidence of such efficiencies and/or methods to evaluate them. Chapter 3 discusses a methodology that could be used to compare the efficiency of PPPs vis-à-vis traditional procurement projects. Chapter 4 presents a case study comparing the routine O&M costs of a group of toll roads managed by both the private and the public sectors in a U.S. state. Conclusions are discussed in Chapter 5. Finally, limitations of this study and recommendations for future work are presented in Chapter 6.

CHAPTER 2: PPPs vs TRADITIONAL DELIVERY FOR HIGHWAY PROJECTS

As summarized by De Corla-Souza et al. (*19*), when a public agency seeks to evaluate highway investment and procurement decisions, that agency can be trying to answer any of four questions. The first two are concerned with how the proposed project could benefit society in general:

1. Will investing in this project yield societal benefits that exceed the costs to society over the long run?
2. Will one method of procurement deliver greater net societal benefits than another method?

These questions address economic efficiency. As such, an appropriate method to address them is a benefit-cost analysis—a comprehensive framework that allows the assessment of a full range of costs, risks, and benefits that can incorporate difficult-to-quantify factors such as externalities.

The last two questions focus on the financial aspects of the procurement decision from the point of view of the public agency's financial balance sheet:

3. What is the best procurement approach?
4. Is the bid price that the private entity in a PPP is offering (or willing to accept) a good value for the public agency?

The answers to these two questions depend on the transaction's financial details. To answer the third question, quantitative VfM analysis is an appropriate tool and as such it has been used in other studies (*19*). On the other hand, to evaluate the bid price in the fourth question, valuation studies based on the discounted net present value of the project's cash flows are generally used (*19*).

Because this study is concerned with the notion of whether private sector practices are more cost-efficient for the delivery and operation of transportation infrastructure, the last two questions are relevant. The third one is of particular interest, as a better understanding of whether the private sector is indeed more efficient could aid decision-makers in their selection of procurement methods.

To understand if and how such notion had been evaluated, a literature review was conducted to identify evaluations of PPPs. The focus was on comparisons between PPPs and traditional procurements, the performance and efficiency evaluations of PPPs, and the O&M phase of PPPs. Studies considered relevant are discussed next.

2.1 COST AND DURATION

Studies about PPP performance have tended to focus on their cost and schedule. This is understandable since, as mentioned in Chapter 1, cost is element the most frequently cited by both PPP supporters and critics to support their positions (*2*). Another fact is that, in traditional procurement, the public sector carries the majority of construction cost and delay risks and therefore cost and time overruns are common (*5*).

Such studies are mostly about the design and construction phases since the majority of projects are still in operation, many in their early years, but also because of the difficulties in obtaining performance data about the O&M phases. Two broad types of comparisons were found in the literature: one comparing the total cost of construction, and the other comparing the cost and schedule changes to the project's contract.

2.1.1 Total Cost

In the frequently cited study *"Ex Ante Construction Costs in the European Road Sector: A Comparison of Public-Private Partnerships and Traditional Public Procurement,"* Blanc-Brude et al. compared the cost of constructing road projects in Europe under PPPs and under traditional procurement to examine whether and by how much construction costs differed. They defined PPPs as DBFOM contracts and traditional procurement as every other model; such classification was based on the premise that non-DBFOM projects involve public rather than private finance, and that it is the private financing element that creates the incentives and risk allocation that define PPPs (*5*).

Their study was based on a review of economic theory that suggested that the ex-ante construction cost of a PPP should be higher than in traditional procurement. The authors summarized the reasons for that as deriving from three main factors:

1. **The control of the asset by the concessionaire:** Under a PPP, the private sector controls the asset, so any gains from making cost-saving investments will be accrued by the concessionaire; this creates an incentive to undertake such investments.
2. **The bundling of asset construction and operations:** Bundling construction and operations into one contract allows positive externalities between those two phases to be internalized by the concessionaire. This incentivizes the concessionaire to seek life-cycle cost savings by making changes during design and undertaking investments during construction to reduce the asset's O&M costs.
3. **The transfer of construction risk to the concessionaire:** On a PPP project, the private partner carries all the construction risks and is compensated for accepting them, whereas on traditional procurement the public sector bears those risks. Consequently, a higher ex-ante construction cost should be expected on a PPP due to the explicit recognition and pricing of the transferred risks.

While recognizing that the costs and benefits of PPPs should be evaluated over a project's entire life cycle up to the end of the contract, Blanc-Brude et al. acknowledged that it was only in the last two decades that PPP procurement started to take off in Europe, and so most projects were still in operation at the time of their study in 2006. As a result, most available information about those projects corresponded to the construction phase; for that reason, their study focused on construction costs only.

The projects to be compared were selected from the database of road projects financed by the European Investment Bank between 1990 and 2005. With data from over 200 projects, a reduced-form empirical model was developed with the natural logarithm of ex-ante unit construction costs, in millions of Euros per kilometer, as the dependent variable. Those unit construction costs included construction work, design, engineering, and supervision, since those items are directly related to the specifications of the project, the authors said. On the other hand, the explanatory variables used could be classified as either economic determinants of construction costs (procurement method and labor costs); technical determinants of road construction costs (type of roadway, number of lanes, terrain, etc.); or country dummies (to capture country-specific attributes such as political features, institutional arrangements, etc.).

The results of their empirical analysis showed that, on average, the PPP projects had 24% higher ex-ante construction costs than the projects delivered by traditional procurement. The authors suggested that such difference could be the result of higher investments made in the design/construction phases to reduce costs during the projects' operations, and of the risk premium charged by the private sector for assuming the transferred risks. Yet, they argued that it could also be the result of other factors, such as the higher bidding cots of PPPs compared to traditional projects, the lower competition in the PPP markets, or even corruption in the awarding of PPPs.

Moreover, it was noted that the estimated 24% difference in ex-ante costs was similar to the typical cost overruns observed in European road projects procured traditionally. According to the authors, such similarity suggested that the bulk of the difference in costs reflected the price that the public sector paid to avoid cost and schedule overruns as well as changes in the projects' specifications, making other sources of higher PPP costs seem less important.

Lastly, Blanc-Brude et al. acknowledged that because their analysis focused only on the construction costs, and did not quantify the impact of such costs on the projects' life-cycle costs or benefits, the results did not allow them to draw normative conclusions about the economic desirability of PPPs as a procurement method. Those types of analyses would require a large number of completed PPP projects (*5*).

2.1.2 Cost and Schedule Changes

To evaluate whether transportation infrastructure projects performed as promised in terms of costs, Flyvbjerg et al. (*23*) analyzed the largest sample of projects at the time (2003), which included 258 projects in 20 countries, valued at approximately US$90 billion (in constant 1995 dollars prices). The results showed with overwhelming statistical significance that in terms of costs, transportation infrastructure projects (of all types) did not perform as promised and, instead, costs were highly uncertain. Specifically, the study found that nine out of ten transportation infrastructure projects suffered cost escalation, with road projects experiencing an average cost escalation of 20%. Cost escalation was found to be a global issue, as it was documented across 20 nations on five continents.

From their results, they concluded that the cost estimates used in public debates and decision-making for transport infrastructure development were highly, systematically, and significantly misleading. Furthermore, they argued that such misleading of costs generated risks that were typically ignored or underplayed in decision-making.

The risk of cost overruns is, along with the risk of schedule delays, one of the main risks typically transferred to the private partner in a PPP. For that reason, our review moved on to explore evaluations of PPPs.

2.1.3 PPP Evaluations in Europe and Australia

Studies to evaluate the cost and schedule performance of PPPs have focused on more mature PPP markets, namely Europe and Australia. Numerous references to their results can be found in the PPP literature. For example, Chasey et al. cites various studies showing that cost and schedule overruns are common in the construction of highways over US$100 million, as found in various countries, including the UK, Canada, and the U.S. (*6*).

Akbiyikli (*22*), Raisbeck et al. (*24*), Hodge and Greve (*10*), and others referenced the findings from the UK's National Audit Office, which in 2003 evaluated 98 projects to find that 76% of private finance initiative (PFI) (the UK term for PPPs) projects resulted in on-time delivery, compared to 30% for the non-PFI projects, and that 79% of the PFIs delivered the asset on budget, versus only 27% of the traditional projects (*25*). Findings from a 2003 study by the HM Treasury, the UK's economic and finance ministry, are also mentioned frequently. Such report found that 88% of PFI projects were delivered on time and 79% on budget (*26*).

Results from many studies can be found throughout the PPP literature suggesting PPPs as a superior model in terms of cost and schedule control as compared to traditional procurement. However, Hodge and Greve pointed out several different reasons that statistically solid evidence to support such a notion is weak and at times controversial (*10*). Raisbeck et al. also echoed critiques made by researchers at University College London (*27*) about the then-existing research on PPP performance, which was suggested to be biased in favor of PPPs.

Addressing most of those identified issues, Raisbeck et al. designed a rigorous methodological approach to compare time and cost in Australian PPPs with projects delivered via traditional procurement methods, motivated by concerns of widespread optimism bias and the lack of appropriate data for capital projects decision-making (*24*).

Separating projects into two pools, 21 PPPs (7 transportation-related) and 33 traditional projects (16 transportation-related) were compared based on publicly available data. Selected projects were those undertaken after the then-latest PPP policy changes in 2000, largely completed, with capital budgets over $20 million. Additionally, the two pools of projects were created with a similar number of projects and with projects of similar complexity.

The results showed superior cost efficiency of PPPs over the traditional projects, as the PPPs presented an average of 2.4% cost overruns between contractual commitment and final outcome, versus 13.8% of traditional projects. Time overruns were 2.5% for PPPs and 2.3% for traditional projects, which the authors characterized as exceptional for PPPs given that they are subjected to additional scrutiny, and that traditional projects were said to have a head start since their general specifications are usually known at the project's announcement.

From those results, it was concluded that PPPs in Australia provided superior performance in terms of both the cost and time. It was also noted that the advantages of PPP increased with the size and the complexity of the projects.

2.1.4 PPP Evaluations in North America

As illustrative as the results from international studies can be to decision-makers in the U.S., those markets are so different that the findings cannot be directly transferable to the North American PPP market (*6*). For that reason, and with the goal of objectively evaluating the performance of very large PPP projects, Chasey et al. performed what they claimed to be the first comprehensive study comparing PPP transportation projects in North America against traditionally delivered projects in a paper called *"A Comparison of PPPs and Traditional Procurement Methods in North American Highway Construction."* For their study, traditional projects were defined as those delivered through any procurement method other than DBFOM.

They conducted a literature review of cost and schedule growth in Design-Bid-Build (DBB) and Design-Build (DB) highway projects and used the results as a benchmark for comparison against a group of PPP highway projects. The two metrics used for the comparison were the average cost change and average schedule change, calculated as the difference between the estimates at the financial close of the PPPs and the actual cost and schedules.

The 12 PPP projects selected for this study were highway and bridge projects constructed between 1990 and 2010, delivered as DBFOMs, with costs between \$90 million and \$1.1 billion. They were all located either in the U.S. or in Canada.

From the literature review, Chasey et al. selected two studies said to provide the best comparisons to their study: the studies by Tom Warne and Associates (*28*), and by Shrestha (*29*). They were selected because they focused on North American projects constructed in the same time period, and within similar cost ranges of the PPP projects. Warne's study, however, did not compare directly the DBB and DB projects but instead asked the project managers of 21 DB projects in the U.S. to estimate the time the projects would have taken if delivered as DBBs. Shrestha's did compare projects: four DB projects across the U.S. against four DBB projects from Texas. The results of the comparisons are seen in Table 1.

Table 1. Results of the Comparison by Chasey et al.

Authors	Projects Compared	Delivery Method	Location	Cost Change (%)	Schedule Change (%)
Chasey et al.	12 DBFOM projects between US$90 and US$110 million	DBFOM	U.S. and Canada	0.81	-0.3
Warne	21 DB projects with costs greater than US$83 million	DB	U.S.	4	-11
Shrestha	4 DBB and 4 DB projects with costs over US$100 million	DBB	U.S.	12.71	4.34
		DB	Texas	1.49	11.04

The comparison showed that the DBFOM projects performed better in terms of cost change (0.81%) than did the DBs (4% and 1.49%), and much better than the DBBs (12.71%). From this, Chasey et al. concluded that the cost control of DFOM projects may be attributable to the DB portion more than the FOM portion, a somewhat adventurous statement if only based on the presented evidence, although they did recommend more research on the topic.

In terms of schedule, they found that of the 12 PPP projects, only one was late while seven were completed early, for an average schedule change of -0.3%. This was compared to the schedule change of the DBs (-11% in Warne's study and 11.04% in Shrestha's) and of the DBBs (4.34%), showing the PPP projects as the better performers and presenting conflicting results about the DB projects. Chasey et al. highlighted that the DB projects in Warne's study performed better than all other projects, including PPPs, and that Shrestha's DB projects performed worse than all other projects, including the DBBs. However, Chasey et al. did not venture to provide an explanation for this result. One possible explanation could be that Shrestha's projects were all from the same state (Texas), which might have had some unique circumstances that affected their performance at the time, while Warner's projects were located across the U.S.

In their summarizing comments, Chasey et al. mentioned that of the 12 PPP projects, 10 did not result in any cost or schedule increase, for an 80% success ratio. Based on their findings, Chasey et al. posed doubts about what they referred to as the conventional wisdom that the construction phase is the riskiest of highway project phases. In reference to the schedule change, they acknowledged the good performance of the PPP projects, which they justified as resulting from the concessionaire's incentive to have the project in operation as soon as possible to start recovering their investment. From that assertion, they claimed that it is expected that PPP projects would be finished on time.

Finally, the authors rightly recognized that, as positive these specific outcomes may be, cost and schedule control are only two of the many aspects of a PPP delivery model. Therefore, they recommended research on other aspects that could result in additional saving and efficiencies, and specifically, on the O&M portion, which they related to the private sector's incentive to produce a better quality project. Because the 12 PPP projects in their study were still in operation at the time of the comparison and thus had not completed their contractual cycle, they suggested a comparison of the life-cycle asset management costs between a PPP and a traditionally delivered project.

In summary, the literature review showed that, as acknowledged by Blanc-Brude et al., *"the comparison of cost* [and schedule] *overruns in PPPs and traditional public procurement is arguably a comparison of apples and oranges"* because there is less incentive to provide accurate construction budgets in traditional procurement as it is the public sector who bears those risks (*5*). Also, since most PPP projects are still in construction or in their early years of operation, most studies focused solely on the performance during the design and construction phases. Yet, for a PPP to offer a greater VfM to the public agency and the project users, there must be other sources of value during the project's life cycle. For that reason, the literature review was extended to explore other types of PPP evaluations.

2.2 EFFICIENCY OF PPPs

Expanding the focus beyond the design and construction phases, the literature review in relation to the so-called efficiencies of the private sector did not yield nearly as many results. Two relevant studies are discussed next.

A paper entitled *"General Framework for Evaluating Long-Term Leasing of Toll Roads. Case Study of Indiana I-90 Highway"* focused on the long-term leasing of toll roads such as the Chicago Skyway in 2005 and the Indiana Toll Road in 2006. According to the authors, such deals resulted in negative public perceptions about taxpayer-funded facilities being offered to private entities with little public control (*1*). Thus, the authors proposed a general probabilistic framework to evaluate long-term leases of toll roads, consisting of an analysis of 1) the PPP's economic efficiency in comparison to in-house toll road management, and 2) the protection of the public interest.

For this assessment, only the economic efficiency evaluation is relevant. In that regard, Zhang et al. used net present values (NPV) to compare the economic efficiency of two scenarios. In the first scenario, the public agency leases the toll road to a private concessionaire; in the second one, the agency continues to operate the toll road over the lease period. In the latter, the agency would need to predict its in-house management revenues and costs over the same period of time as the proposed lease to compare them with the price offered by the private sector for leasing the toll road.

For the privatization scenario, it was assumed that the public agency would receive an up-front payment for the lease with no revenue or risk sharing; thus, because the analysis was done from the point of view of the agency, this up-front payment was the only factor to be considered for the NPV analysis, as the agency would relinquish control of the facility.

For the in-house management scenario, the NPV of all revenues, including uncertainties in the evaluation factors, were calculated as follows:

$$R(\varepsilon_R) = \sum_{i=1}^{n}[\frac{v_i(\varepsilon_v) * t_i(\varepsilon_t)}{(1 + r_i(\varepsilon_r))^i} + \frac{or_i(\varepsilon_{or})}{(1 + r_i(\varepsilon_r))^i}]$$

where:
R = present worth of total revenues in lease period,
v_i = traffic volume in year i,
t_i = average toll for unit traffic in year i,
or $_i$ (ε_{or}) = other revenues excluding toll revenue in year i,
n = total years of lease period,
r_i = discount rate in year i, and
ε_R, ε_v, ε_t, ε_{or}, and ε_r = uncertainties related to toll revenue, traffic volume growth, toll rate growth, other revenues, and discount rate.

The NPV of the costs were estimated as:

$$C(\varepsilon_C) = \sum_{i=1}^{n}\frac{o_i(\varepsilon_o) * p_i(\varepsilon_p) + oc_i(\varepsilon_{oc})}{(1 + r_i(\varepsilon_r))^i}$$

where:
C = present worth of total costs in entire lease period,
o_i = operating costs in year i,
p_i = preservation costs in year i,
oc_i = other costs in year i, and
ε_o, ε_p, *and* ε_{oc} = uncertainties related to operating costs, preservation costs, and other costs.

By comparing the NPVs of the two scenarios, Zhang et al. suggested that the public agency could evaluate the relative economic efficiency of the two alternatives. Then they wondered about possible reasons for the two NPVs to be different. In other words, what could be the rationale for privatization?

Responding to their own question, they suggested two possible answers: one focusing on revenues and one focusing on costs. For the former, they argued that a public agency would not increase toll rates as frequently or as high, therefore collecting less revenue; for the latter, they claimed that the private sector tends to exhibit relatively superior operating efficiencies and use more advanced maintenance technologies, implying reduced costs. Such claimed efficiencies by the private sector are what concern this study.

A case study of the Indiana I-90 toll road lease was done to illustrate the proposed framework and an NPV analysis (based on a Monte Carlo simulation) was done to account for the uncertainties in the framework's inputs. The results indicated that from a purely financial perspective, the public agency made the right decision by privatizing the toll road.

A different type of analysis was undertaken by researchers at George Mason University with the same goal of evaluating the efficiency of PPPs. In a paper titled *"Efficiency of Public-Private Partnerships: A Frontier Analysis of Highway P3s,"* Daito and Gifford argued that previous studies have evaluated the performance and efficiency of PPPs through statistical analyses but that approach is problematic for two reasons: 1) in the U.S. the number of completed PPP projects has not been large enough to allow rigorous statistical analysis, and 2) those analyses require *a priori* functional forms to be specified, making them difficult (*18*).

To circumvent those issues, and as an initial step toward the comparative evaluation of cost efficiency between PPP and traditionally procured projects, the authors evaluated the efficiency of PPP delivery—measured as cost savings—using frontier analysis, a framework that has been employed to investigate the production of goods and services in various contexts. Specifically, Data Envelopment Analysis (DEA) was used. DEA is a non-parametric approach to conduct efficiency analysis of multiple inputs and/or outputs of a production process; it imposes minimum assumptions and does not require the specification of an *a priori* functional form for empirical estimation.

The authors claimed to be the first to use non-parametric frontier analysis in the context of PPPs, and that they did it to explore whether such a framework could be used to address the efficiency question. Their study used roadway projects as the Decision Making Units (DMUs), and project delivery as the production of those DMUs. DMUs were defined for this study as tolled or non-tolled road capacity expansion projects delivered as DB, DBF, Design-Build-Maintain (DBM), or DBFOM contracts. Such procurement models were selected, authors said, because they involve considerable risk transfer compared with the traditional DBB model.

The model used project costs as the input and the delivered roadway projects as the output to evaluate 37 projects in the U.S., several of which are located in states considered PPP leaders: California, Florida, Texas, and Virginia. The model's input variable was the projects' total cost at the financial close (in 2012 dollars), while "lane-mileage," "the number of bridges," and "the number of interchanges" were the output variables. However, acknowledging severe limitations on the availability of data, the authors recognized that these types of projects are quite complex and as such their output should include more variables.

Their analysis calculated global and local efficiency scores and scale efficiency, as well as increasing/decreasing returns to scale for each DMU. Yet, unusual results arose, including extremely low efficiency scores for many DMUs and large gaps between the actual and the target inputs. The authors hypothesized that this was due to the need for more sophisticated variable specifications to better capture project outputs and activities, and for better data quality.

For future research, they suggested the incorporation of environmental and socio-economic factors, such as the urban or rural character of the project, the area's per capita income, and many others, due to the likelihood of such factors affecting DMU efficiency levels and cost structures. Including them would, according to the authors, deepen the understanding of the relationships between institutional and market conditions and project performance and would allow the use of the proposed framework to aid decision-makers in their selection of procurement mechanisms for the delivery of infrastructure.

In their concluding remarks, Daito and Gifford recognized the challenges to empirically evaluate whether the cost savings presumption under which PPPs were originally proposed holds true in actual projects. In that regard, they assessed the contribution of their study as an early empirical analysis on the relative costs of U.S. PPPs and one of the first studies to use DEA to analyze the efficiency of infrastructure projects.

2.3 PERFORMANCE OF PPPs

The long-term nature of a PPP gives rise to project components and risks not typically found in a traditional project, some of which can change dynamically over the life of the project. Consequently, evaluating a PPP project is more difficult than evaluating a traditional project, and therefore the use of time and cost measurements do not reflect the complexity associated with PPPs. This is the premise behind an Australian study titled *"Conceptual Framework for the Performance Measurement of Public-Private Partnerships"* (*12*).

In that paper, a literature review performed by Liu et al. showed that performance measurement in the construction industry has focused on product-oriented measures; this means that the performance indicators used to evaluate construction projects are established after the project has been completed. In the same way, the development process of a PPP project has been subjected to evaluation only in its final phase, making it only a review, and therefore an ineffective way to try to control and improve the delivery of the asset. This is important because the lack of a life-cycle perspective in the performance measurement, juxtaposed with dynamic measures, can contribute to inefficient and ineffective decision-making (*30*).

The life cycle of a PPP project can be grouped into three major phases: initiation and planning; procurement; and partnership (construction, operation, and maintenance) (*31*). Thus, Haponava and Al-Jibouri suggested that a dynamic life-cycle perspective should be used to measure the performance of a PPP project with a phase-based evaluation to replace the traditional product-oriented approach (*30*).

Liu et al. considered that performance evaluation of PPPs has received limited attention, in particular in terms of their dynamic life cycle. For this reason, they proposed a conceptual dynamic life-cycle performance measurement framework for PPP infrastructure projects that can deal with the complexities arising from having multiple stakeholders (*12*). They decided to use the *performance prism* based on the arguments of Neely et al. (*32*), which considered the prism a holistic framework capable of dealing with multiple stakeholders and guiding the design of performance measurement for long term success in a business environment. The performance prism consists of five interrelated facets: stakeholder satisfaction; strategies; processes; capabilities; and stakeholder contribution.

Typical evaluations of PPP projects occur either at the initiation stage (ex ante) or at the end of the project (ex post). But, according to Haponava and Al-Jibouri, they fail to effectively and efficiently control the entire development process of the project (*30*). To make it a comprehensive life-cycle evaluation, Liu et al. suggested placing two evaluation nodes between the "pre-tendering" and the "bidding" phases, and between the "contract and financial close" and the "contract management" phases, as shown in Figure 1. With four evaluation nodes, project managers could then measure project performance in each life-cycle phase using a set of core indicators (CIs) that they derived from the literature on PPP performance measurement.

Ex-Ante Evaluation 1	Project Selection & Definition	PPP Option Assessment	Getting Organized	Pre-tendering Work	Evaluation 2	Bidding	Contract & Financial Close	Evaluation 3	Contract Management	Ex-Post Evaluation 4

Figure 1. Proposed Evaluation Nodes within the Life Cycle of a PPP.

Adapted from the "Dynamic life-cycle performance measurement framework of PPP projects" proposed by Liu et al.

The proposed life-cycle evaluation is dependent upon continuous improvement. As such, learning mechanisms have been embedded into the framework to assist organizations in systematically acquiring their lessons learned. The authors argued that, using their proposed framework, PPP project managers can grasp the project's performance information by analyzing the developed CIs at each evaluation node, which would provide them real-time performance review capabilities. This method would help project managers to identify how well their resources were utilized in the previous phase, what should be done to improve, and what should be the focus in the subsequent phase. Lastly, the paper recognizes that their proposed framework has not been validated, but that ongoing research is in progress to test it through case studies and surveys.

Overall, Liu et al.'s proposed evaluation framework is said to help capture some of the dynamism of a PPP project by using the performance prism with the set of phase-based indicators proposed. As such, it should help improve project performance evaluations even while the project is under way, giving it a sort of "real-time" capability. Yet, while the proposed framework can be of great help to PPP project managers by providing detailed insights into the project's effectiveness and efficiency, its use would not be appropriate for comparing them to traditionally developed projects because the latter are by nature fragmented into pieces for which different parties are responsible, with each party interested in and responsible for only for their piece.

2.4 OPERATIONS AND MAINTENANCE IN PPPs

One method to evaluate the performance of a PPP during the O&M phase could be to benchmark actual performance data against an appropriate standard. Such standards can vary and may include the original contract, the public sector comparator, performance data from similar facilities that were procured traditionally, and performance data from private competitors of the private partner (*33*).

Two of those methods have been documented in this study to evaluate the design and construction phases: benchmarking against conventional procurement and benchmarking against the original contract. However, their use for the evaluation of the O&M phase is problematic because most PPPs in the U.S. are recent; few projects have been in operation long enough to provide adequate performance data for comparison. There is also the issue of data confidentiality and the difficulty of having a private entity share their proprietary performance data. Additionally, in the case of benchmarking against the original contact, since the O&M phase in a PPP concession is usually very long, changes in the requirements would not be unexpected—which would complicate the comparisons between the original specifications and the tasks actually performed (*33*).

Perhaps for these reasons, the literature review did not find adequate empirical evaluations of the O&M phase of PPPs in the road sector. A different approach to evaluate the performance of a concessionaire in the O&M phase is discussed next.

In the UK, PFI projects are designed to fund long-term infrastructure and public services; they are the equivalent (and some argue the precursors) of what other countries call PPPs. In a 2002 paper titled *"Operation and Maintenance (O&M) Management in PFI Road Projects in the UK"* (*20*), Akbiyikli and Eaton cited a report from the UK's Private Finance Panel (*34*) arguing that a PFI is designed not to borrow money from the private sector but to transfer risk to the private sector. Coupled with efficiencies in management, a PFI's resulting benefits would outweigh the higher costs of private funding, resulting in greater value to taxpayers. This is the same argument that resonates with PPP supporters in other countries.

Under that premise, and the idea that the O&M is the most important phase in a PFI project (as it is the time at which the service is delivered and the payment conditions are created), Akbiyikli and Eaton examined the then-current O&M management practices in PFI road projects in the UK (*20*). Based on two DBFOM empirical case studies, they proposed a conceptual framework for the O&M management of PFIs that identified physical and functional performance as the critical O&M criteria.

Because DBFOM contracts are output focused, they define a functional specification; thus, the PFI output specifications clarify the functional requirements and the physical performance criteria. Thus, the public sector specifies the requirements (the *what*) and leaves the private sector to determine the best way to meet those requirements (the *how*), which is supposed to incentivize the private sector to innovate in the design and the provision of the O&M services to meet the specified outputs.

Their proposed O&M life-cycle management framework has two primary parameters: physical performance and functional performance, which the authors said should be defined concurrently and cannot be separated. The physical performance parameters relate to the asset; e.g., the maintenance, durability, and environmental impacts of road projects. The functional performance parameters relate to the appropriate functioning of the asset; e.g., driving comfort, safety, and ease of access.

The secondary parameters of their framework were defined as innovation, effectiveness, efficiency, and certainty, all of which are to be measured relative to the output specifications defined by the public sector in terms of time, cost, and quality, the authors said. Efficiency, which is the focus of this assessment, is defined as the minimization of resources required to deliver the agreed outputs at appropriate quality levels. It is thus concerned with the ratio of inputs to outputs and is said to reflect the management of the delivery and operation of the roadway throughout its life.

From their analysis of the two case studies and interviews with staff from the projects private partners, Akbiyikli and Eaton concluded that the functional and performance requirements have to be considered at the beginning of the project, and that the management of the O&M has to focus on the delivery of the services by minimizing the O&M expenses while maximizing the quality of those services (*20*). They arrived at such conclusions based on the considerations of the staff in the sense that taking a life-cycle approach to the management of the roads translated into higher construction quality than in traditional procurement, which in turn reduced the need for longer term maintenance throughout the life of the project. In that sense, the projects achieved efficiency.

While their paper was strictly theoretical and the framework seemed unpractical at first, as there were no indications of how it was to be used, in a subsequent study Akbiyikli applied the framework to a PFI road project on the eastern coast of Scotland: the A92 project. As documented in the paper titled *"Performance Assessment of a Private Finance Initiative Road Project,"* the objective was to examine whether the performance in the operations phase of that project effectively complied with the output specifications to the satisfaction of the road users (*22*).

Based on a survey and a semi-structured interview, Akbiyikli examined the first four years of the O&M phase of the A92 project to assess whether the road users were satisfied with the performance of the PFI project. In that regard, according to the author, the study used a "phenomenological qualitative approach" to "inductively and holistically understand human experience in the specific setting of a PFI project" (*22*). In simpler terms, it sought to evaluate whether the users were satisfied with the project without searching for the causes of their satisfaction or their lack of it.

The study analyzed the project's Customer Satisfaction Surveys from the period between 2005 and 2009, using the results of the first year (2005–2006) to benchmark the customers' perception about the O&M contractor's performance. The results of the last two surveys were said to show very high percentages of users indicating that the performance of the O&M contractor was above average when compared with that of similar roads and many survey responses were said to include complimentary comments.

According to the author, the Customer Satisfaction Survey results showed that the A92 project satisfied all the performance criteria: strategic objectives, efficiency, service delivery outcomes, quality, and effectiveness. For that reason, Akbiyikli concluded that after four years of operation the A92 concession year was performing very well and to the satisfaction of both the public and private partners as well as its customers.

Akbiyikli's paper illustrated a different type of evaluation method than the ones discussed before, as it focused on qualitatively assessing the performance of the project from the point of view of the users. While it was based on a single project and therefore it does not allow generalizing about PPP as a procurement method, it was said to provide a very good indication of the subject (*22*). Another issue is that the results were not compared against a traditionally procured project. However, such a comparison would only require conducting similar surveys to obtain comparable data.

In summary, assessing the satisfaction of PPP customers is important and should be encouraged as part of a more comprehensive evaluation of the real benefits of PPPs beyond the mere financial aspects. Also, benchmarking actual O&M performance data from a PPP against a traditionally procured project, while difficult to do, could provide definite insights into the so-called efficiencies created by the involvement of the private sector.

CHAPTER 3: METHODOLOGY TO COMPARE THE LIFE-CYCLE EFFICIENCY OF PPPs AND TRADITIONALLY PROCURED PROJECTS

The literature review demonstrated that overall comparisons of the benefits and costs of PPPs vis-à-vis traditional procurement are difficult and require comprehensive evaluation frameworks. Moreover, it was shown that empirically determining whether or not PPPs result in more efficient life-cycle management than traditional procurement is difficult: an individual project cannot be assessed until it has completed its contract cycle, and a system or program cannot be assessed until a sufficient number of projects are completed.

3.1 PROPOSED METHODOLOGY

From the evaluation methodologies reviewed in Chapter 2, the authors find the one proposed by Zhang et al. as the most appropriate for comparing the life-cycle economic efficiency in the delivery, operation, and maintenance of toll roads for the public and private sectors. The reasons for this preference are the methodology's life-cycle approach, simplicity, and the capability of its probabilistic nature to incorporate the inherent uncertainties of the inputs. Besides, the framework can be used in a multiple-scenario approach; for this assessment, scenario one would be a DBFOM concession, and scenario two a publicly developed and managed project.

Zhang's paper illustrated the use of the framework with a case study that evaluated the leasing of a toll road against the alternative of continued in-house management by a public entity. While that example was correctly analyzed, to be able to compare a DBFOM concession, as it is the interest of this study, two changes would be needed.

First, the private sector scenario should include the toll revenues over the life of the concession (instead of consisting only of an up-front lease payment). Thus, the NPV of the DBFOM scenario would result from contrasting the concession's life-cycle revenues and costs over the contract period using the following two formulas:

1. To estimate the concession's revenues:

$$R(\varepsilon_R) = \sum_{i=1}^{n}[\frac{v_i(\varepsilon_v) * t_i(\varepsilon_t)}{\left(1 + r_i(\varepsilon_r)\right)^i} + \frac{or_i(\varepsilon_{or})}{\left(1 + r_i(\varepsilon_r)\right)^i}]$$

where:
R = present worth of total revenues in concession period,
v_i = traffic volume in year i,
t_i = average toll for unit traffic in year i,
or $_i(\varepsilon_{or})$ = other revenues excluding toll revenue in year i,
n = total years of concession period,
r_i = discount rate in year i, and

ε_R, ε_v, ε_t, ε_{or}, and ε_r = uncertainties related to toll revenue, traffic volume growth, toll rate growth, other revenues, and discount rate.

2. To estimate the concession's costs:

$$C(\varepsilon_C) = \sum_{i=1}^{n} \frac{o_i(\varepsilon_o) * p_i(\varepsilon_p) + oc_i(\varepsilon_{oc})}{(1 + r_i(\varepsilon_r))^i}$$

where:
C = present worth of total costs in entire concession period,
o_i = operating costs in year i,
p_i = preservation costs in year i,
oc_i = other costs in year i, and
ε_o, ε_p, and ε_{oc} = uncertainties related to operating costs, preservation costs, and other costs.

The second change would be in the estimation of the annual operating costs. In Zhang's case study, as mentioned before, the private sector alternative comprised only the up-front lease payment and no estimation of costs was needed since the analysis was done solely from the point of view of the public entity. Conversely, in the continued in-house management scenario, annual operating costs were estimated by fitting a statistical function to the historic annual operating costs since the facility had been in operation by the same public entity. Because a DBFOM is a greenfield project, neither sector can provide historic operating costs. Therefore, the method used by Zhang is not appropriate for the estimation of such costs.

The easiest way to estimate the annual operating costs would be, if possible, to fit historic data from similar facilities in the geographic vicinity of the study facility that are under the management of the same public entity for which scenario two (a publicly developed and managed project) is being developed. However, as mentioned before, the literature on PPPs and PPP stakeholders argue strongly that the private sector is more efficient than the public sector. So, if true, that would mean that it is unlikely that a private concessionaire would incur similar operating costs as a public entity.

Since most operating PPP projects in the U.S. have only recently started operations, they are at this time subject to routine O&M activities that can then be empirically evaluated. To assess any differences in routine O&M costs between private and public toll facilities, a set of indicators is proposed next and a limited-scope case study is presented in Chapter 4.

3.2 PROPOSED COMPARISON INDICATORS

To evaluate cost differences in toll road management between the public and the private sectors, the following indicators can be used:

3.2.1 Cost per Mile

These indicators provide an assessment of the O&M expenditures (OPEX) per the length and/or operational capacity of a roadway.

- **OPEX per center-mile:** A measure of the proportion of O&M spent in relation to the length of the facility.
- **OPEX per lane-mile:** Analyzing costs per lane-miles instead of per centerline-miles provides a more detailed picture of the proportion of costs spent in relation to the operational capacity of the facilities.

3.2.2 Cost per Unit Sold

Assessing the amount of OPEX incurred against the usage of the facilities, these indicators depend on the volume of traffic on the facility.

- **OPEX per VMT:** One way to measure facility usage is by calculating the total amount of vehicle miles travelled (VMT) on it.
- **OPEX per number of toll transactions:** Another road-usage metric, this measures the amount spent on O&M in relation to the number of times a vehicle passes through a toll gantry.

3.2.3 Productivity

In the U.S., labor is an expensive element in managing a roadway. The following metrics help to evaluate the efficiency of a facility in terms of labor usage by using full-time equivalent employee figures.

- **Number of employees per mile:** How many full-time equivalent employees are being used per each mile of the facility.
- **Miles per number of employees:** The opposite of the previous indicator, this estimates how many miles of the roadway are, in theory, under the responsibility of each of the employees.
- **Lane-miles per number of employees:** This metric uses lane-miles to assess capacity (rather than simply the facility's length).

3.2.4 Operating Expense Ratio

This is used to estimate the efficiency of a facility's management by comparing what it costs to operate it against the revenue it generates; see Table 2.

- **OPEX per toll revenue:** This metric estimates the proportion of the toll revenues that are being used to operate and maintain the facility.

Table 2. Proposed Comparison Indicators.

OPEX		
Type	**Indicator**	**Unit**
Cost/Mile	OPEX/Mile	($/Mile)
	OPEX/Lane-Mile	($/Lane-Mile)
Cost/Unit Sold	OPEX/VMT	(¢/VMT)
	OPEX/Transaction	($/Transaction)
Operating Expense Ratio	OPEX/Toll Revenue	(%)

To illustrate the use of these indicators, an empirical analysis was conducted to assess the cost efficiency differences between public and private sector entities in the management of tolled roadways in a U.S. state. A limited-scope case study format was used and is presented in the following chapter.

3.3 FACTORS TO CONSIDER FOR AN ADEQUATE COMPARISON

For a comparison to be effective and fair, the compared facilities should have relatively similar characteristics; if not, efforts should be made to try to "level the field." In the case of large road infrastructure projects such as toll roads, attaining a level playing field is difficult since all such projects are unique. Thus, for a detailed comprehensive cost performance comparison to be made between different types of projects, it is important to consider the following factors:

- **Type of highway:** Whether it is a limited access highway or other type
- **Greenfield vs. brownfield:** Whether the facility is to be built on a clear site (greenfield project) or is a retrofit or expansion (brownfield)
- **Location:** The geographic location of the facility and the character of the area (urban or rural) make a difference in the type and amount of traffic, and in the availability and cost of labor, materials, and equipment required to perform O&M activities.
- **Traffic volume:** The wear and tear of a roadway is directly related to the type and amount of traffic on it. Therefore, it is important to determine the forecasted traffic volumes, as well as its composition (proportion of light and heavy vehicles), because of the significant effect of weight on the pavement.
- **Pavement type:** Rigid and flexible pavements have very different service lives and therefore differences in the amount and timing of required maintenance and repairs. For this reason, the type of pavement is likely one of the most important factors to consider when comparing the life-cycle performance and cost of operating a roadway. To account for those differences and to be able to compare their annual O&M costs, one alternative is to convert their estimated life-cycle costs into Equivalent Uniform Annual Costs.

- **Frontage roads:** The existence of frontage roads adjacent to the compared facilities not only increases the amount of required O&M activities, it can also increase their complexity if they have different pavement types than the mainline lanes. Therefore, including the frontage roads in the comparison provides a more detailed look into the cost performance of the facilities.
- **Area of bridges:** As with frontage roads, the presence, type, and quantity of bridges can have important consequences for the O&M costs of a facility and it is therefore important to include them in the evaluation.
- **Number of toll gantries/ramps:** The type, amount, and location of toll gantries and ramps have diverse effects in a toll road facility. For example, the O&M of the equipment requires specialized knowledge that can be either contracted out or provided in-house. Moreover, in addition to the toll collection point locations, whether the tolls are collected electronically in tollbooths can be an important determinant in drivers' decisions of whether to use the facility, which in turn affects the amount of revenues collected and the wear and tear on the facility.
- **O&M decision-making approach:** A concessionaire is typically a stand-alone private firm (or a special-purpose vehicle) that is created by the project's private investors for the sole purpose of managing the concession. Because it is only focused on managing one project, its management is done at a project level: its decision-making and funding are dedicated to that one facility, which is an optimal arrangement for all the involved parties (the public agency, the private investors, and the facility users). On the other hand, when a public entity is in charge of managing roadways, it is typically in charge of a network of facilities instead of just one. Additionally, public entities usually receive their funding from annual budgets allocated by governmental entities to operate the entire network; consequently, their decision-making is made at a network level. Because frequently the allocated funding is not enough to maintain the entire network at the highest performance levels, public entities are faced with the need to prioritize how to spend their allocated funds, which is a sub-optimal approach. These differences in what a concessionaire and a public agency can do to manage their facilities should be considered
- **Other:** There are additional factors that should be taken into consideration, such as who is in charge and under what conditions in an emergency, intelligent transportation systems (ITS), disaster evacuation, etc.

CHAPTER 4: CASE STUDY COMPARISON OF OPERATION AND MAINTENANCE COSTS

The purpose of this case study is to perform a limited-scope comparison of the differences in the routine O&M costs of a group of toll roadways in the U.S. The compared facilities are operated by either the public sector (a State Department of Transportation [DOT]) or the private sector (a private concessionaire). The objective is to show the use of the comparison indicators proposed in Chapter 3 to evaluate whether the private sector is more efficient in the management of roadways, as argued in the PPP literature and circles.

Managing a tolled highway is a very complex issue; it not only includes the planning, oversight, and implementation of a number of technical and administrative activities, but it also involves the responsibility for handling large budgets and responding to a variety of stakeholders (government agencies, road users, investors, etc.). Depending on whether the roadway is managed by a public or a private entity, and on its location, type, size, and many other aspects, the degree of importance given to each of such factors may vary, but ultimately it is their combined effect that translates into the success or failure of the management endeavor.

One important aspect common to these types of enterprises is the need to maintain certain information confidentiality, primarily for two reasons. First, most concessions and some publicly owned toll roads are funded by private investors; second, public access to financial and management strategies could expose the entity or its parent entities to unwarranted exposure and reduced competitive advantage in future projects. For those reasons, to protect the confidentiality of the data presented in this assessment, this is a "blind" case study, meaning that the names, locations, and owners/managers of the facilities are not disclosed. Therefore, any identifying information has been removed to the maximum extent possible, including references to the sources of the data used.

4.1 DESCRIPTION OF COMPARED FACILITIES

This case study focuses on a group of toll roadways in the U.S. One toll road was developed under a DBFOM type of PPP, as a toll concession agreement; it was therefore designed and built by a private concessionaire, the same entity that is in charge of its O&M. This facility will be referred to as "the concession," and it will serve to illustrate the characteristics of a privately managed roadway.

To contrast the private concession model to a public management model, a group of toll roads located in the vicinity of the concession was selected. These facilities were developed under more traditional procurement models: either as DBB or DB contracts and all of them are under the management of a State DOT. This group of toll roads was selected because they are close to the concession, owned by the same DOT that arranged the concession, and collectively managed as a system. For the remainder of this study they will be referred to as "the system."

4.2 STUDY PERIOD

The study period is one year; however, the DOT records expenditures in a fiscal year basis while the concessionaire records expenditures on a calendar year basis. While consideration was given to matching information from one entity to the other entity's format, since seasonal incidents such as exceptional weather conditions or similar events could translate into abnormal operations of a facility, it is not considered that this was the case during such period. Besides, as mentioned earlier, the purpose of this comparison is only to provide a broad illustration of the cost differences in the management of toll roadways. Therefore, it was decided to maintain data in their original format. As a result, the system data corresponds to fiscal year 2013 ending August 31, 2013, while the concession's data corresponds to the 2013 calendar year, ending in December.

4.3 CHARACTERISTICS OF THE COMPARED FACILITIES

The following attributes of both the concession and the system serve to give the reader an idea about their physical and operational characteristics. They are also key inputs for the comparison.

- **Type of roadway:** All the roadways in this case study are toll highways.
- **Length:**
    - **Centerline Miles:** The concession has approximately 40 centerline miles (of the mainline lanes), while the system has approximately 73.
    - **Lane-miles:** Including ramps, the concession has approximately 160 lane-miles; the system has about 345 lane-miles.
- **Annual Average Daily Traffic (AADT):** During calendar year 2013, the concession served approximately 5,564 vehicles per day. In fiscal year 2013, the system served approximately 130,820 vehicles each day.
- **Annual Vehicle Miles Travelled (VMT):** Because no actual VMT data was obtained, based on the AADT and the centerline miles and assuming each vehicle traveled the entire length of the road, estimated VMT in the concession were 81,157,679 miles during 2013, while vehicles in the system were estimated to travel 735,970,669 miles in fiscal year 2013.
- **Toll Transactions:** For the study period, the number of toll transactions for the concession was about 5,153,558, with approximately 102,507,240 for the system .
- **Toll Revenue:** For the study period, the total amount of toll revenue collected in the concession was an estimated $18,854,588; in the system, the total toll revenue was approximately $103,984,500.

- **Number of Employees:** As will be discussed later in detail, it was not possible to determine the number of employees in charge of managing the system. As a result, the related comparison indicators could not be used.

Due to the lack of readily available information about certain characteristics of the system, not all of the proposed indicators could be used. Table 3 summarizes the physical and operational characteristics of the concession and the system used in the comparison.

Table 3. Characteristics of the System and the Concession.

	System	Concession
Mainline Lanes		
Centerline miles	72.8	40.0
Lane-miles	345.3	159.9
Annual VMT	735,970,669	81,157,679
AADT	130,820	5,564
Toll Transactions	102,507,240	5,153,558
Toll Revenue	$103,984,500	$18,854,588

4.4 SUMMARY OF THE OPERATIONS AND MAINTENANCE COSTS

This section summarizes the annual OPEX incurred by both the DOT and the concessionaire while operating and maintaining their respective facilities.

4.4.1 Cost Differentiation

Differentiating between direct and indirect costs is key for an appropriate cost analysis. Direct costs, as defined by the White House’s Office of Management and Budget, are those costs that can be identified specifically with a particular cost objective, which in a road maintenance context includes salaries, materials, equipment, and other costs paid for work performed on a maintenance job (*2*). Conversely, indirect costs, also known as overhead, are those costs incurred for a purpose benefiting more than one cost objective and that are not readily assignable to the cost objectives specifically benefitted without disproportionate efforts. These include, for example, oversight and supervision of a maintenance office to the benefit of all maintenance jobs within its jurisdiction, but with no direct nexus to each individual maintenance job (*2*).

4.4.2 Availability of Cost Data

The success of any research study depends on the type and quality of data used. In this case, access to detailed proprietary technical and cost information was needed about the facilities that comprise the system and the concession and therefore data requests were sent to both the DOT and the concessionaire.

It should be recognized that despite its private nature, the concessionaire was open and responsive to all data requests. On the other hand, and while recognizing the great disposition and responsiveness of some of the DOT's staff, the system's detailed cost information requested was not provided. The reason given by the DOT's legal department was that because the system is funded by private investors, they were concerned about the possibility of potentially confidential information being made public. As a result, no financial information was released other than publicly available information and, importantly, no clarifications about published information were provided.

As a result of this non-disclosure of information, the authors could not clearly identify which of the system's costs were direct or indirect and how many DOT employees supported the management of the system during the study period. For this reason, the classification of the system's costs presented in this case study (as either direct or indirect) is the result of the author's best judgment interpretation of publicly available financial reports. The concessionaire, on the other hand, did provide its own classification of direct and indirect costs.

Lacking the input of the DOT about how its costs should be classified, the more unbiased way to compare the system and the concessionaire costs would be to use the same criteria to classify the costs of both. In this case, that meant using a similar type of classification for the system as the one used by the concessionaire. In short, the principle used by the concessionaire to categorize its costs seems to have been the direct relationship with the O&M of the facility. For example, categories like "personnel," "third-parties," "materials," and "utilities" were classified as direct costs when they involved activities like "roadway maintenance," "tolling maintenance," and "traffic management center," but classified as indirect costs when involving other activities. Following the same principle, activities like "public relations and communications," "financial" and "business development," among others, were classified as indirect costs.

However, the level of detail of the system's published information does not allow accomplishing that classification easily either (see Table 4 for the system's cost categorization). For that reason, it was decided to create two different scenarios for the system's data, based on the categorization principle used by the concessionaire, but with different levels of rigor.

Table 4. Categories of Operating Expenses of the System.

Operating Expenses
Professional Fees and Services
Salaries
Materials and Supplies
Communication and Utilities
Repairs and Maintenance
Printing and Reproduction
Contracted Services
Advertising
Other Operating Expenses

Scenario 1. Under this scenario, the only cost classified as direct was that of the "Repairs and Maintenance" category (Table 5). While that might seem extreme, this category is the only one with a name that can be easily related to the O&M of the facility, due to the lack of information about the subcategories or the nature of some of the categories used.

Table 5. Assumed Cost Classification under Scenario 1.

	Direct Cost	Indirect Cost
Operating Expense		Professional Fees and Services
		Salaries
		Materials and Supplies
		Communication and Utilities
	Repairs and Maintenance	
		Printing and Reproduction
		Contracted Services
		Advertising
		Other Operating Expenses
Total	**$16,247,417**	**$31,132,386**
Percentage of Total	**34.29%**	**65.71%**

Scenario 2. This scenario took a broader consideration of the reasons of why a cost category could be classified as direct (Table 6). In addition to the "Repairs and Maintenance" category included in scenario 1, the category "Contracted Services" was also classified as direct because the system has contracted out both its maintenance and toll collection operations. The other category included in this scenario was "Salaries," because the management and supervision of those contracts, as well as the management of the system, are performed by DOT staff. While the authors recognize that the two latter cost categories could include costs from other activities that

are not as directly related to the actual O&M, with the limited information available it is not possible to separate them.

The category "Professional Fees and Services" was not assumed to be direct because it likely entails activities performed by consultants, such as those that help the DOT with capital planning, budgeting, and related issues.

Table 6. Assumed Cost Classification under Scenario 2.

	Direct Cost	**Indirect Cost**
Operating Expense		Professional Fees and Services
	Salaries	
		Materials and Supplies
		Communication and Utilities
	Repairs and Maintenance	
		Printing and Reproduction
	Contracted Services	
		Advertising
		Other Operating Expenses
Total	**$30,410,863**	**$16,968,940**
Percentage of Total	**64.19%**	**35.81%**

Overall, the system had operating expenditures of $47.3 million, of which 34.29% were assumed to be direct costs and 65.71% indirect costs under scenario 1. Under scenario 2, 64.19% were assumed to be direct costs with 35.81% assumed to be indirect. The concession had a total of $10.3 million in total OPEX with 56.81% direct and 43.19% indirect, as identified by the concessionaire (Figure 2).

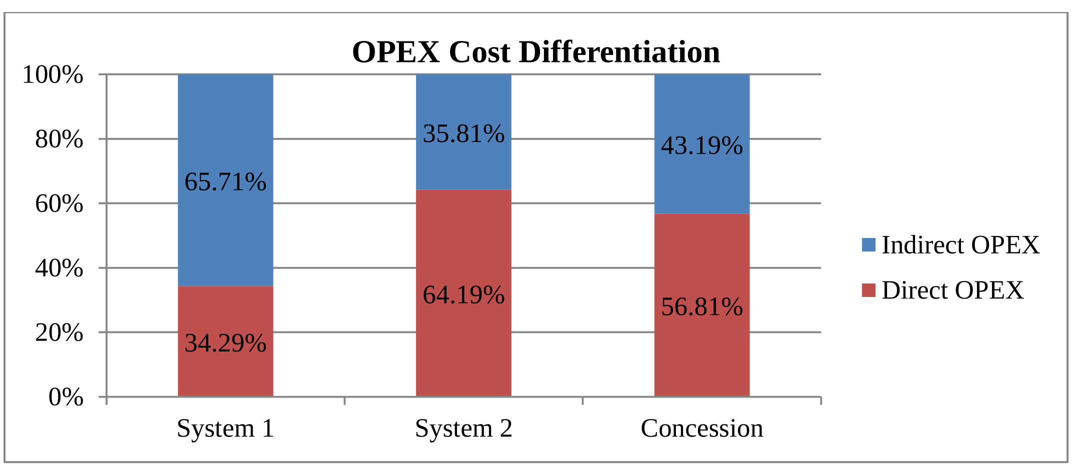


Figure 2. OPEX Cost Differentiation for the System and the Concession during the Study Period.

Source: Author's interpretation of the system's financial statement, and concessionaire.

4.5 COMPARISON RESULTS

Because it is important to differentiate the type of costs when talking about efficiency, the comparison was done in two ways: first, for the total OPEX and then for the direct and indirect OPEX under each of the two scenarios. In all cases the system was used as the baseline against which the concession's costs were compared; therefore, in the following tables the values shown in the columns labeled "Difference" indicate the percentage difference that the concessionaire spent compared to what the DOT spent. In other words, a positive amount indicates that the concessionaire spent more than the DOT for that variable, while a negative value indicates the opposite. Tables 7 to 9 present the comparison results.

Table 7. Comparison of Total OPEX Concession vs. System (Baseline).

Indicator	Unit	Concession	System	Difference (%)
OPEX/Mile	($/Mile)	257,929	650,821	**(-60.37)**
OPEX/Lane-Mile	($/Lane-Mile)	64,482	137,213	**(-53.01)**
OPEX/VMT	(¢/VMT)	12.70	6.44	**97.30**
OPEX/Transaction	($/Transaction)	2.00	0.46	**332.75**
OPEX/Toll Revenue	(%)	54.67%	45.56%	**19.99**

Table 8. Comparison of Direct OPEX (D.O.) under Scenarios 1 & 2. Concession vs. System (Baseline).

<table>
<tr><th rowspan="3">Indicator</th><th rowspan="3">Unit</th><th rowspan="2">Concession</th><th colspan="4">System</th></tr>
<tr><th colspan="2">Scenario 1</th><th colspan="2">Scenario 2</th></tr>
<tr><th>D.O.</th><th>D.O.</th><th>Difference (%)</th><th>D.O.</th><th>Difference (%)</th></tr>
<tr><td>OPEX/Mile</td><td>($/Mile)</td><td>146,530</td><td>223,179</td><td>(-34.34)</td><td>417,732</td><td>(-64.92)</td></tr>
<tr><td>OPEX/Lane-Mile</td><td>($/Lane-Mile)</td><td>36,632</td><td>47,053</td><td>(-22.15)</td><td>88,071</td><td>(-58.41)</td></tr>
<tr><td>OPEX/VMT</td><td>(¢/VMT)</td><td>7.22</td><td>2.21</td><td>226.85</td><td>4.13</td><td>74.63</td></tr>
<tr><td>OPEX/Transaction</td><td>($/Trans.)</td><td>1.14</td><td>0.16</td><td>616.92</td><td>0.30</td><td>283.02</td></tr>
<tr><td>OPEX/Toll Revenue</td><td>(%)</td><td>31.06%</td><td>15.62%</td><td>98.78</td><td>29.25%</td><td>6.20</td></tr>
</table>

Table 9. Comparison of Indirect OPEX (I.O.) under Scenarios 1 & 2. Concession vs. System (Baseline).

Indicator	Unit	Concession	System			
			Scenario 1		Scenario 2	
		I.O	I.O.	Difference (%)	I.O.	Difference (%)
OPEX/Mile	($/Mile)	111,399	427,643	**(-73.95)**	233,090	**(-52.21)**
OPEX/Lane-Mile	($/Lane-Mile)	27,850	90,160	**(-69.11)**	49,143	**(-43.33)**
OPEX/VMT	(¢/VMT)	5.49	4.23	**29.68**	2.31	**137.92**
OPEX/Transaction	($/Trans.)	0.86	0.30	**184.44**	0.17	**421.86**
OPEX/Toll Revenue	(%)	23.61%	29.94%	**(-21.13)**	16.32%	**44.70**

4.6 DISCUSSION OF FINDINGS

4.6.1 Total OPEX

As seen in Figure 3, the comparison of total operating expenses among the publicly and the privately managed facilities showed that the concessionaire spent a lower proportion of OPEX per centerline mile (-60.37%) and per lane-mile (-53.01%) than the DOT did. Both of these metrics are measures of cost efficiency in relation to the size and operational capacity of the facilities. Ergo, during this study's analysis period the concessionaire was more efficient in the operation and management of its facility in relation to its physical size and capacity than was the DOT for its system.

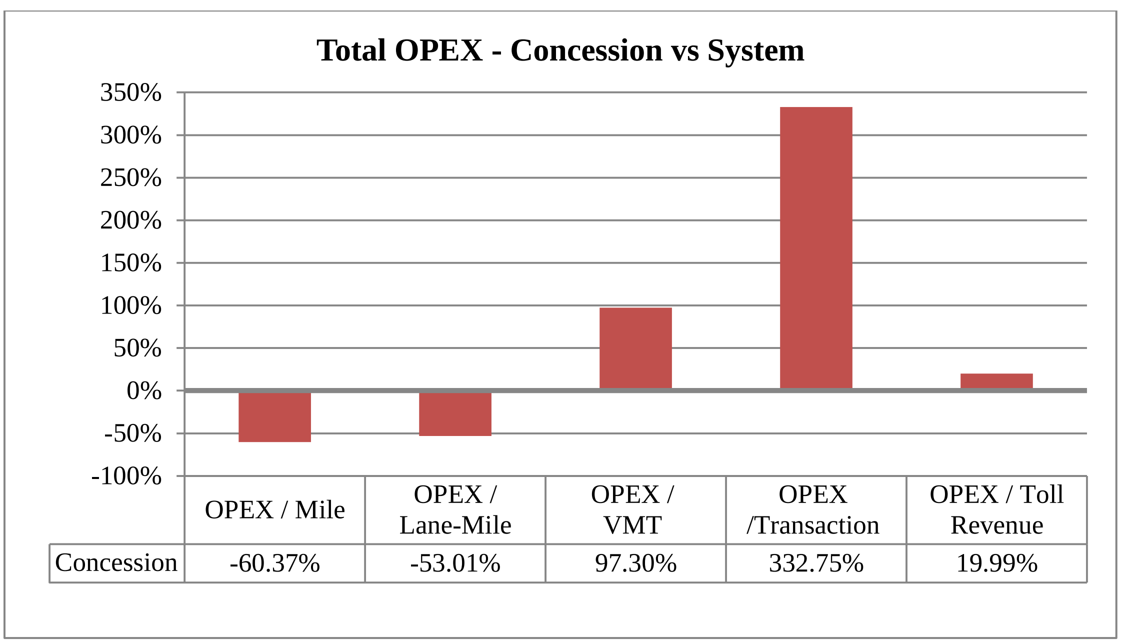


Figure 3. Graphical Comparison of Total OPEX.

On the other hand, the concession had higher OPEX in relation to the three metrics that depend on the traffic volume: VMT, number of transactions, and toll revenue. In this regard, the DOT was more efficient than the concessionaire during the study period by 97.3%, 332.75%, and 19.99%, respectively. However, the concession has been in operation for a shorter period of time than the system's roads and it is still in its initial ramp-up period. Thus, its traffic volume was significantly lower than the system's volume even when weighted by mileage (see Figure 4).

The large difference in the traffic volumes complicates the comparison of the traffic-dependent metrics. But, if traffic volumes increase in the concession and start reaching volumes closer to the forecasted numbers, the efficiency of the concession will likely improve and the gap with the system's numbers could shrink. However, whether the concession's efficiency indicators will match or outperform the system's numbers is not known, as the operation of a facility of this type is subject to several sources of uncertainty that could affect these metrics.

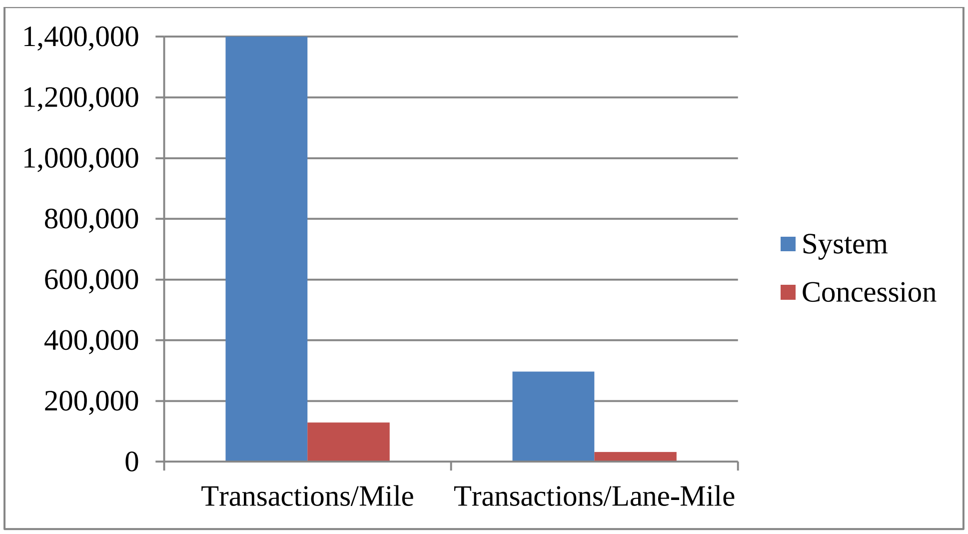


Figure 4. Difference in the Number of Toll Transactions per Mile and per Lane-Mile between the System and the Concession.

4.6.2 Direct OPEX

Scenario 1. With the operating expenditures categorized under scenario 1, direct costs were compared (see Figure 5). The authors found that if the assumed cost categorization of this scenario was realistic, the concession was more cost-efficient than the system in regard to centerline miles and lane-miles by 34.3% and -22.1%, respectively. Because direct costs are the expenditures that result in the actual O&M of the roadways (including materials, equipment, labor etc.), and since the facilities are located generally in the same geographic area (so in theory those costs should not differ greatly), these results signal a more efficient use of resources by the concessionaire under these assumptions. These differences are even more meaningful under an extreme scenario such as this one, which characterized only one of the cost categories as direct costs.

When the other set of indicators were evaluated, the percentage differences were largely favorable to the system, as the concessionaire was assumed to have spent 226.8%, 616.9%, and 98.7% more per VMT, per number of transactions, and per toll revenue, respectively, than the DOT. This indicates that based on the traffic-dependent indicators under scenario 1, the DOT would have been extremely more cost-efficient in terms of direct costs than the concessionaire. Yet, while these results point toward the same trend found with the total OPEX, the large increase in the magnitude of the differences is due to the fact that scenario 1 was extreme in the sense that only one cost category was considered direct cost, meaning a small amount.

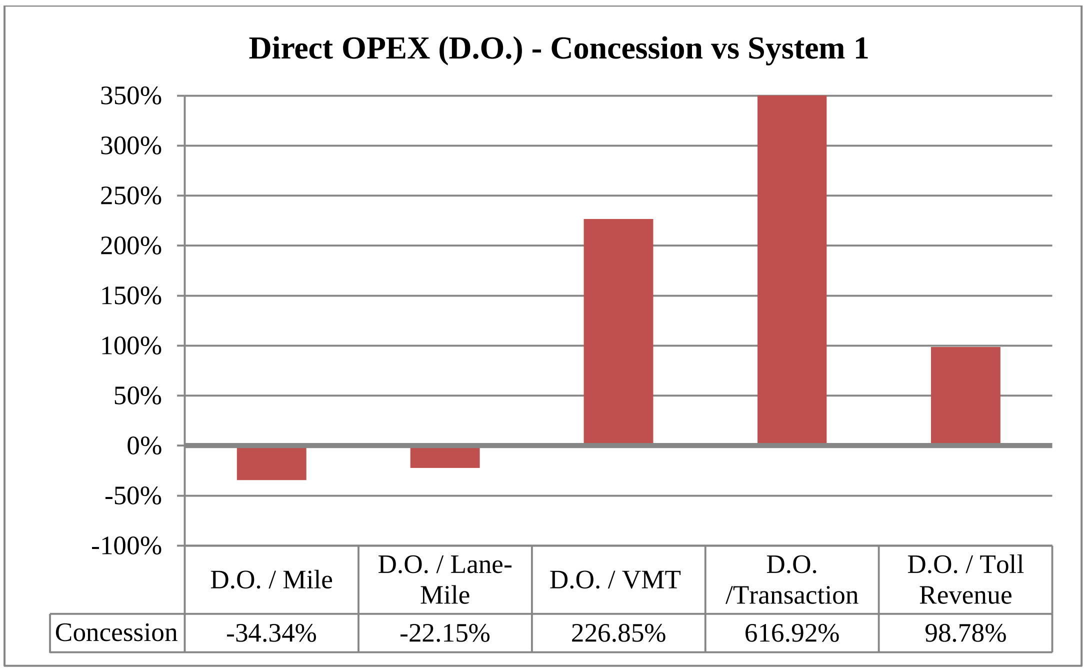


Figure 5. Graphical Comparison of Direct OPEX under Scenario 1.

Scenario 2. Under scenario 2, the concessionaire was assumed again not only to be more cost efficient than the DOT in regard to miles (-64.9%) and lane-miles (-58.4%), but by a differential at least twice as big. Evidently this is the result of a larger amount of money classified as direct under this scenario, which included two more cost categories in addition to scenario 1 (see Figure 6).

In terms of VMT, number of transactions, and toll revenue, the system was assumed under this scenario to be more cost efficient than the concession, although by much smaller margins: 74.6%, 283%, and 6.2%, respectively. As mentioned before, this is the result of having a larger proportion of the costs classified as direct. Something to note is that, despite the overwhelmingly larger traffic volumes in the system, the difference in the direct operating expense ratio (direct OPEX/toll revenues) would have been only 6.2% higher than that of the system if the assumed cost classification was appropriate.

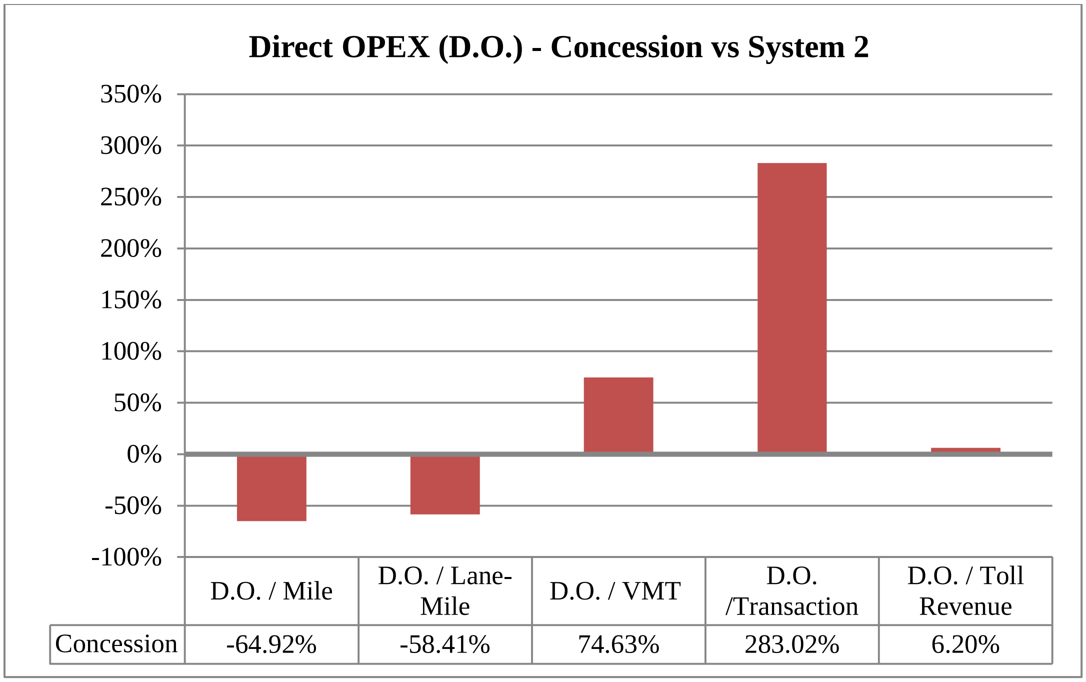


Figure 6. Graphical Comparison of Direct OPEX under Scenario 2.

4.6.3 Indirect OPEX

Scenario 1. Regarding the indirect costs, under scenario 1 the concessionaire spent approximately 73.9% less in overhead per centerline-mile and 69.1% less per lane-mile than the DOT. Regarding VMT and number of transactions, the overall trend remained, showing that the system would have been more cost-efficient than the concession, although by much smaller margins: 29.6% and 184.4% respectively. With scenario 1 classifying most of the costs as indirect, the increase in the magnitudes of the differentials in favor of the concession when compared to the total OPEX per mile and per lane-mile are indicators is no surprise.

In contrast, the indirect operating expense ratio (indirect cost per toll revenue) under scenario 1 showed that the concession was 21.1% more cost efficient than the system (see Figure 7); in other words, the concessionaire is assumed to have spent 21.1% less in overhead costs in relation to the toll revenue it collected than the system did. While it is recognized that scenario 1 characterized most of the system's costs as indirect, this result is still interesting since it reversed the overall trends that showed the system as more cost-efficient in terms of the three traffic-related indicators under all other scenarios and cost analyses.

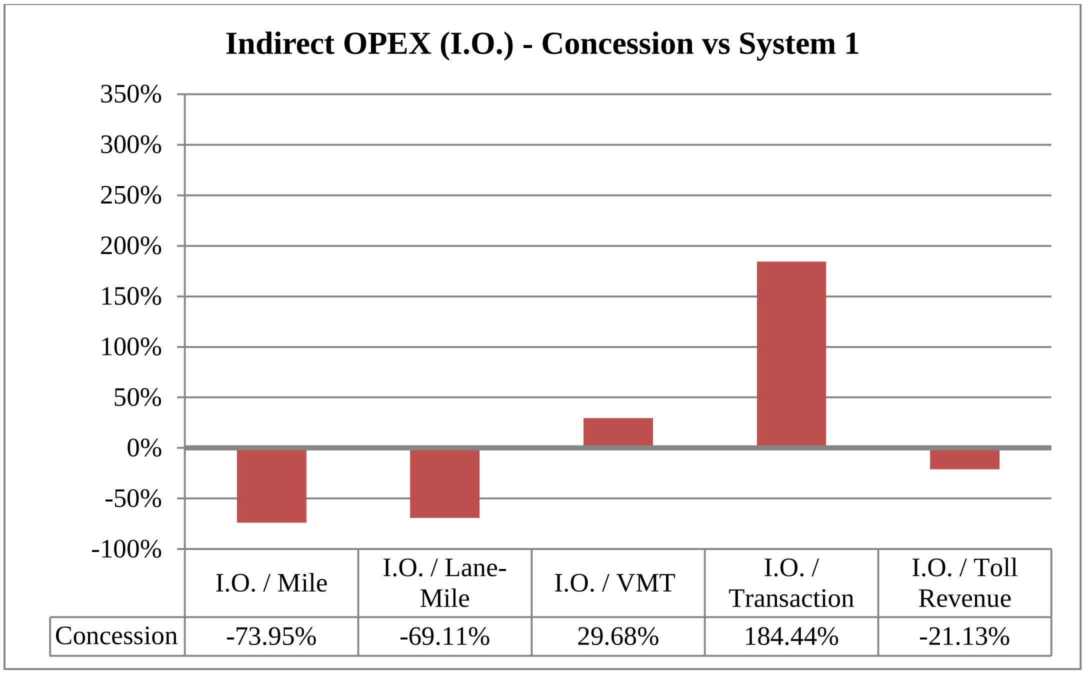
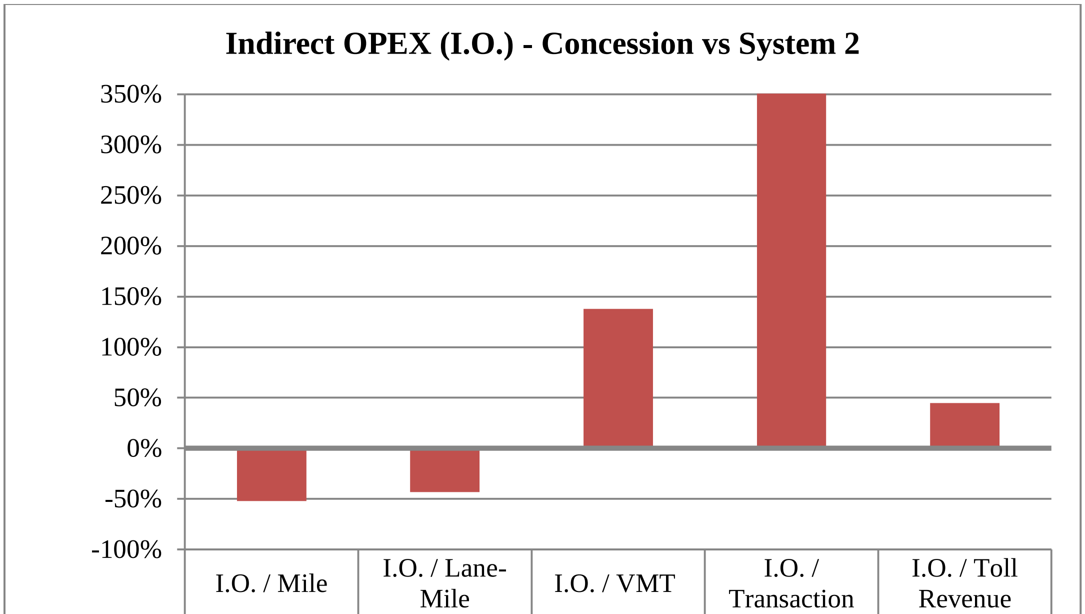


Figure 7. Graphical Comparison of Indirect OPEX under Scenario 1.

Scenario 2. The decrease in the proportion of indirect cost in this scenario compared to scenario 1 evidently translates into a reduction of the magnitude of the differentials between the indirect costs indicators. However, the concessionaire continued to appear more cost-efficient in terms of miles (-52.2%) and lane-miles (-43.3%), as in all the scenarios and analyses.

All three traffic-dependent indicators showed a better cost-efficiency by the DOT under scenario 2 assumptions (see Figure 8). Specifically, the system would have spent 137.9% less in regard to VMT, 421.8% in terms of number of transactions, and 44.7% less in indirect costs per toll revenue.



	I.O. / Mile	I.O. / Lane-Mile	I.O. / VMT	I.O. / Transaction	I.O. / Toll Revenue
Concession	-52.21%	-43.33%	137.92%	421.86%	44.70%

Figure 8. Graphical Comparison of Indirect OPEX under Scenario 2.

4.6.4 Summary

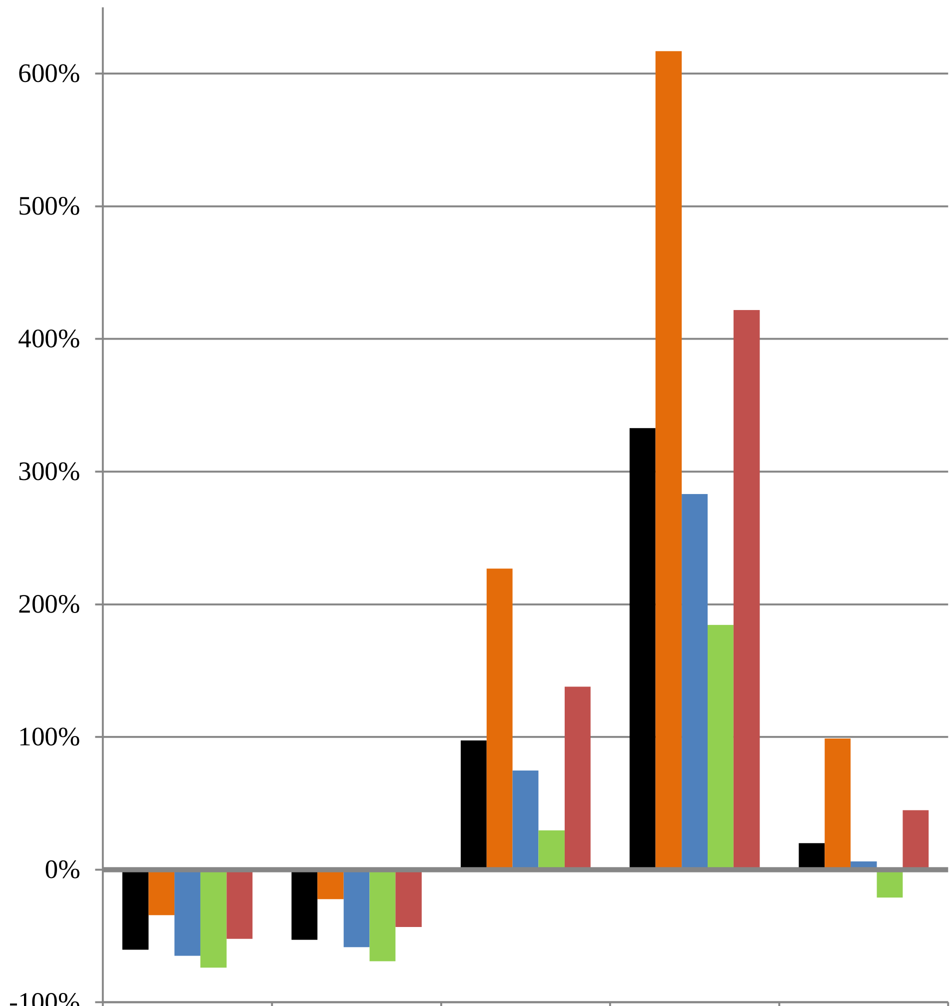
The comparison found that the concessionaire was more cost-efficient in terms of total OPEX and in terms of the assumed direct and indirect OPEX per mile, and per lane-mile than the DOT. The DOT was shown to be more cost efficient than the concessionaire for all types of OPEX (total and assumed direct and indirect) in relation to the number of VMT and the number of toll transactions. However, those two metrics depend on the amount of traffic volume on the facilities—during the study period, traffic volume was overwhelmingly greater on the system, helping it to spread its costs over a much larger base. If and when the concession reaches higher traffic volumes (as it ends its ramp-up period), the gap with the system’s numbers could decrease.

Special attention should be given to the operating expense ratio (OPEX per toll revenue), a useful and simple tool to estimate cost-efficiency in the O&M of different facilities, because of its distinct behavior in this study. This ratio indicated that the DOT-managed system was more efficient in terms of total OPEX. However, once again it should be noted that, like the two previous indicators, this one depends on traffic volume, a factor that favors the system’s cost efficiency. When direct costs were analyzed under the conservative scenario 2, the concessionaire was assumed to have spent only about 6% more than the DOT.

This finding is important because direct costs are those directly related to the actual O&M work, but the system has contracted out its maintenance to a private contractor, while the concessionaire uses its own employees to perform the O&M activities. Therefore, this could be an indication that that the concessionaire is in fact more efficient in the performance of the O&M activities than the DOT maintenance contractor.

While there is no definite data to support it, one hypothesis could be that, as suggested by the literature, the DBFOM concessionaire made certain decisions during the design and/or construction phases with the goal of minimizing the life-cycle operation of its facility. Another reason could be that, since the contractor was not involved in the design and/or construction of the system's roads, its fees include a cost element that accounts for the risks it takes for maintaining a set of facilities for which it cannot vouch. Figure 9 presents all the comparison scenarios in a graphical manner.

OPEX - Concession vs System (1&2)



	OPEX / Mile	OPEX / Lane-Mile	OPEX / VMT	OPEX /Transaction	OPEX / Toll Revenue
Total OPEX	-60.37%	-53.01%	97.30%	332.75%	19.99%
Direct OPEX (1)	-34.34%	-22.15%	226.85%	616.92%	98.78%
Direct OPEX (2)	-64.92%	-58.41%	74.63%	283.02%	6.20%
Indirect OPEX (1)	-73.95%	-69.11%	29.68%	184.44%	-21.13%
Indirect OPEX (2)	-52.21%	-43.33%	137.92%	421.86%	44.70%

Figure 9. Graphical Comparison of all OPEX and Scenarios.

CHAPTER 5: CONCLUSIONS

The literature on PPPs argues extensively that the private sector is more efficient than the public sector in operating road infrastructure, and identifies this efficiency as one of the main benefits of PPPs. Yet, those studies don't provide empirical support for such a claim. Therefore, this study conducted a four-prong investigation: first, it searched the literature for evidence of those efficiencies as well as methods to evaluate them. Second, it proposed a simple way to compare life-cycle cost efficiency in toll roads. The results showed the following:

1. The conducted literature review found no empirical evidence for superior cost-efficiency of PPP concessionaires in the O&M phase.
2. The majority of studies comparing PPPs against publicly developed projects were focused on design and construction costs and schedule overruns, some of which used not-so-rigorous evaluations as pointed out by other researchers.
3. Some studies that assessed performance and/or efficiency during a project's life cycle were at times highly theoretical and the methods they use are not likely being employed outside of academia.
4. The NPV-based probabilistic framework proposed by Zhang et al. to evaluate the life-cycle economic efficiency of leased toll roads could also be used, in a scenario analysis, to evaluate the life-cycle efficiency of DBFOM projects against traditionally developed projects. The framework is useful due to its simplicity, life-cycle approach, and the ability to evaluate uncertainty. Yet, in Zhang's study, the annual operating cost, one of the framework's inputs, was not evaluated as part of the private management scenario; for the public scenario, it used historical data since the toll road was already in operation. Therefore, a methodology to estimate the annual operating costs for both the public and private scenarios is not available for the evaluation of greenfield projects.

Third, to empirically test the assumption about the private sector's greater efficiency in roadway operation, a set of simple comparison indicators were proposed. Fourth, to illustrate the use of these indicators, a limited-scope case study was performed to compare the routine O&M expenditures of a concession against those of a system of publicly managed toll roads, yielding these results:

1. There were significant differences between the privately and the publicly managed facilities in terms of the cost efficiency of the routine O&M activities. Specifically:
    - The concession was more cost-efficient in terms of OPEX per mile and per lane-mile than was the system. The system was more cost-efficient than the concession in relation to the number of VMT and the number of toll transactions. Yet, those indicators depend on the traffic volume on the facilities, which during the study period was overwhelmingly greater on

the system, helping it to spread costs over a much larger base. If and when the concession reaches higher traffic volumes as it ends its ramp-up period, the gap between the concession's and the system's numbers is likely to decrease.

2. The operating expense ratio (OPEX/toll revenue) indicated that, overall, the DOT-managed system was more efficient than the privately managed concession. However, toll revenue is also a factor of traffic volume.
3. The difference in managing a network of facilities (as public agencies typically do) versus managing a single facility (as concessionaires do), was evident in terms of coordination between different sections within the entities. Some DOT staff lacked a basic understanding of the system's management, financial, and performance characteristics; this was not an issue with the concessionaire's staff.

CHAPTER 6: LIMITATIONS AND FUTURE WORK

The main limitation of this assessment was the non-disclosure of the public toll road system's detailed financial data. Citing confidentiality concerns, the DOT's legal department forbade any release or clarification of financial information. As discussed in Chapter 4, this created the need for the authors to assume what costs were to be classified as direct or indirect and eliminated the possibility of assessing efficiency in terms of number of employees. On the other hand, the private concessionaire, despite being privately funded and managed, had no reservations about sharing their financial and physical information.

Another limitation of the case study was the inability to use more comparison indicators—such as OPEX per area of bridges, OPEX per miles of frontage roads, and other similar metrics—due to the lack of readily available information about some of the DOT system's physical characteristics. This issue further limited the comprehensiveness of the case study's evaluation

FUTURE EFFORTS

While the case study showed differences in cost-efficiency in routine toll road O&M activities between the public and private sectors, additional research should be done to empirically test the hypothesis of the private sector's greater efficiency in delivering and managing road infrastructure. While it would be interesting if other methodologies were proposed, Zhang et al.'s proposed framework can be used in future efforts, as it is simple and easily understood by decision-makers and stakeholders, an important consideration that is sometimes forgotten by academics. However, adequate data and assumptions about O&M costs are needed to be able to produce adequate results. For that, more comprehensive case studies than this one should be performed, using either the proposed or similar indicators to obtain sufficiently detailed empirical data. Additionally, the factors identified as necessary to adequately make comparisons should be evaluated.

The results of those assessments will help public sector decision-makers to decide whether to procure a project as a PPP, and aid concessionaires wanting to evaluate themselves against public agencies, or when entering new markets. Ultimately more comprehensive studies can help to either prove or disprove the still unsupported claims found in the literature today.

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