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Efficiency Based Comparison of Project Delivery Methods

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ABSTRACT

Public Private Partnerships (PPP) are the future of infrastructure project delivery. Majority of the PPPs have been successful except a few over the past decade. The reasons for their failure are well documented by researchers. The misconceptions about PPPs make it increasingly difficult to pursue projects using PPP delivery system. One of the root causes of the misconceptions is from the ambiguities arising from qualitative data and assessments. To overcome this issue, efficiency-based comparison of project delivery methods utilizing Data Envelopment Analysis (DEA) for decision making is presented through this paper. Proposed approach uses qualitative ratings and harnesses the integral utility of the ratings obtained while conducting objective assessment of qualitative data. California's Presidio Parkway Project is used for case study analysis and the data is varied to create three hypothetical scenarios to determine sensitivity of the model. Results from case study are consistent with actual project implementation and the sensitivity analyses result are found to be consistent.

Keywords: Public Private Partnerships, Data Envelopment Analysis, Decision Making, Qualitative and Quantitative Data.

1. INTRODUCTION

Once a leading economy in infrastructure competitiveness, United States (US) has been consistently trailing at least 10 ranks behind other countries over the past five years (CBS News, [1]; PBS News, [2]; World Economic Forum 2017-2018 Data [3])). The US economy is significantly reliant on the existing highway infrastructure, majority of which was built in the 1960s (McBride, [4]). But the infrastructure is rapidly deteriorating and is deemed insufficient to match with the current transportation demands. Construction employs 7 million people through 680,000 companies and create infrastructure worth nearly $1.3 trillion each year (AGC, [5]). Such a huge amount of money moves between construction stakeholders when the contractual obligations are successfully met. But according to a report by ASCE [6] US government requires $1.1 trillion by 2025 to meet the demand of surface transport projects. Government has no source to fund this deficit other than the budgetary provisions. One of the possible solutions could be to involve the private sector. Public Private Partnership (PPP) is proving to be one of the tools through which significant private funds can be leveraged toward government projects. Although it is not a new concept it has not been fully exploited in the US. As per World Bank review, 48 projects worth $61 billion were pursued between 2005 and 2014 with almost 80% completed successfully (Deye, [7]). PPPs enable the public sector to share risks and rewards in non-traditional ways with the private sector, strengthening possibilities of better project outcomes.

Many countries such as the United Kingdom (UK), Australia, Canada, Ireland, India, Portugal, Spain, Turkey, and Japan have used different types of PPP for better outcomes and for a variety of projects. Highways, metro rails, airports, bridges, hospitals, schools, prisons, and water treatment plants are some of the projects completed using PPP project delivery (Kwak et al. [8]; Cui et al. [9]). Depending on the project type and other requirements, various types of PPP have been implemented (World Bank, [10]).

The funding deficits and the infrastructure demand paved the way for PPPs in the US during the early 90s. Since then, PPPs have been increasingly used to deliver public infrastructure in the US. Investment in PPP projects increased by five times between 1998-2007 and 2008-10 (Engel et al. [11]) and the trend is continuing (PWC, [12]). In addition, the constantly increasing demand to add new roads and maintain aging infrastructure combined with the increasing financial deficits implies increased use of PPPs in the US (PWC [12]; White House [13]).

While PPPs played an important role in reducing the US public agencies' financial gaps, a few PPPs failed to achieve their intended objectives (Deye, [7]; Engel et al. [11]; Buxbaum and Ortiz [14]). Despite 80% successful execution, the PPP sceptics have often used the remaining handful of unaccomplished examples to malign PPPs, thus devaluing the important role PPPs played (Deye, [7]). One of the issues that enabled maligning PPPs is from the lack of transparency in decision making process and the inherent limitations of the methodology used to justify PPP project delivery. The methodology requires estimating and comparing holistic values expected out of the PPP versus the traditional project delivery route. The route that is expected to provide better value is recommended for project delivery. Till date, Value for Money (VfM) is the most widely used approach and agencies put significant efforts to determine the best project delivery option. However, the inherent uncertainties and assumptions in VfM make them vulnerable to manipulations (Garvin, [15]) leading to suboptimal decisions and thus failures. The failed PPPs triggered public scepticism over public sector's decision-making capabilities (Buxbaum and Ortiz, [14]). The Government Accountability Office (GAO) conducted a study to evaluate the use of PPPs for protection of public interests (GAO [16]). In its report, the GAO recommended that transportation agencies develop and conduct rigorous upfront analyses to protect public interests. Similarly, the Bipartisan Policy Center (BPC) also expressed concerns about the same issue and recommended that the government agencies up their game when considering PPPs. The BPC analysed the Long Beach Courthouse Project and found that the litigation "highlight(ed) the need to develop an agreed-upon methodology that states across the country can use to analyse the value-for-money offered by a P3 approach compared with a traditional procurement" (BPC, [17].). Similar concerns are echoed by international agencies, industry and researchers.

A World Bank report discusses various VfM deficiencies and draws attention towards striking the right balance between qualitative and quantitative assessment components (World Bank, [18]). Similarly, an article by industry participant have expressed same concerns about the VfM (Ernst and Young Report, [19]). Researchers like Garvin [15], Chan et al [20], Leigland & Shugart [21], and Grimsey & Lewis [22] have cautioned about limitations of VfM assessments saying that results could be dubious and could also lead to inaccurate VfM assessments. Although, agencies have improved the project delivery selection process, there exists a wide scope of improving it. One of the ways the processes can be improved is by supplementing the existing methods used to justify PPP selection.

This paper presents a framework for efficiency-based comparison of PPPs and traditional project delivery method using Data Envelopment Analysis (DEA) model, an advanced optimization model. DEA seamlessly integrates quantitative and qualitative data to obtain a unified relative efficiency score thus reducing subjectivity and increasing transparency. Based on the efficiency score an unambiguous decision can be made. To demonstrate the application and usefulness of DEA model to PPPs, this research includes application of DEAs to Presidio Parkway Project. The results indicate that the DEA model can be effective in accepting or rejecting a project delivery options and thus strengthen the existing decision-making process. This work also aligns with the recommendations by Government Accountability Office (GAO) that called for conducting rigorous analysis ensuring accountability in PPPs.

This paper is organized in eight sections. The following section describes the research need and motivation for this research while highlighting the limitation of existing practices. The DEA model is introduced in the third section. California's Presidio Parkway Project case study analysis is demonstration in the fourth section which includes details about setting up DEA model for the case study. The fifth and sixth sections include results and discussion respectively. The discussion section is dedicated to results' discussion, validation and their connection with PPP decision making. This also includes a sub-section, aiming to show the possible uses of DEAs in procurement. The seventh includes recommendations that will help agencies to adopt DEA models. The paper ends with conclusions drawn from the research. An appendix is provided that includes in-depth details about setting-up the DEA model to facilitate analysts adopt and apply the model on other PPP projects.

2. RESEARCH MOTIVATION: THE AWAITED EVOLUTION OF EVALUATION METHOD

Historically PPPs have evolved significantly but the assessment methods did not evolve at the same pace (Tsukada [23]). This is particularly important because over the years, the projects have grown in enormous complexity requiring a better way to evaluate them. So, there exist a need to enhance the existing assessment methods to suit the evolving PPPs.

Government agencies around the world, including the US, use VfM assessment to determine if a candidate project can be pursued via PPP project delivery route (Morallos et al., [24]). Through the VfM assessment, an agency compares delivery of a candidate project via the traditional (Design-Bid-Build (DBB)) and PPP project delivery routes. The assessment includes five steps. First, all the plausible PPPs are identified for a candidate project. Second, the project risks are analysed via each PPP. Third, a cash flow analysis is conducted considering in-house project delivery via traditional approach and a Net Present Value (NPV) is obtained. The resulting outcome is called a Public Sector Comparator (PSC). Fourth, other cash flow analyses are conducted considering each PPP project delivery and Shadow Bids are obtained. Finally, the non-financial factors influencing the project delivery methods are subjectively combined with the NPV and a final decision is made. This process is outlined in Figure 1.

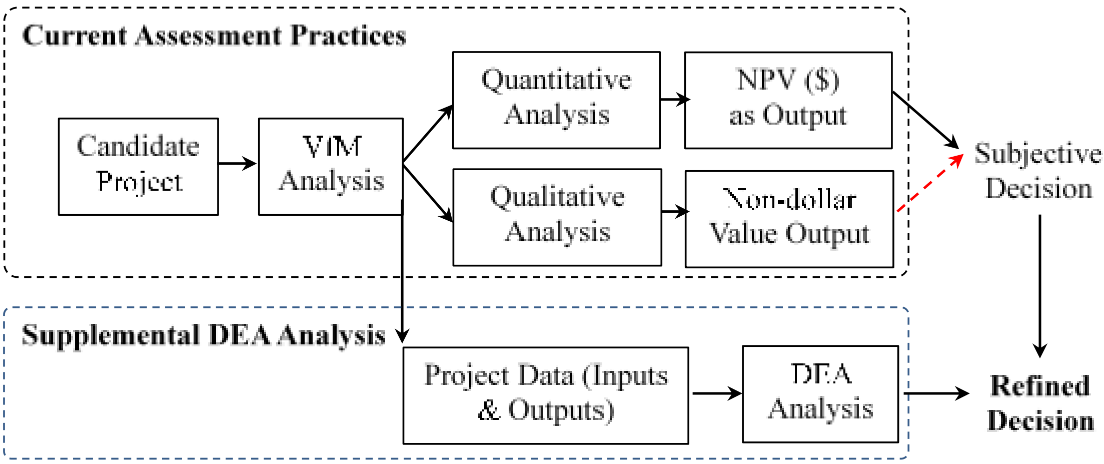

Figure 1. The DEA Analysis Supplementing Current Assessments.

As shown in Figure 1, the VfM assessment gives us a quantitative and a qualitative outcome. The quantitative outcome consists of a crisp numerical value like the NPV of the estimated cash flow. But the qualitative component consists of the non-dollar valued aspects of the project including efficiency and effectiveness. As per the current practices, the VfM qualitative and quantitative outcomes are subjectively combined to reach a final decision (Infrastructure Australia [25]; HM Treasury [26]; Innovative Program Delivery [27]; Partnerships British Columbia [28]). But due to the subjectivity, such decisions become vulnerable to challenges, and litigation in courts (Garg and Garg, [29]). Clearly, the process of combining qualitative component with quantitative component has been a challenge, little attention is paid towards improving this approach.

This research is built on all the previous research to supplement the current decision-making methods. Through this paper a DEA model framework is proposed to supplement current assessment practices. DEA is not a new technique to decision making. Ozbek et al. [30] and Tatari and Kucukvar [31] have used DEA models for construction management problems and similarly it has been used for efficiency-based comparisons in various other fields, but their application to PPPs have not been studied. This research for the first time uses DEA model for comparing PPPs with traditional project delivery method. In this paper we demonstrate calculating relative efficiencies obtained from DEAs using the same data that is used to conduct VfM assessment. Besides combining quantitative and qualitative data the DEA model calculates relative efficiencies. The relative efficiency scores will reduce subjectivity from decision making process for selecting or rejecting PPP project delivery.

3. DEA MODEL FOR RELATIVE EFFICIENCY COMPARISON

DEA is an advance optimization technique that was developed for measuring performance efficiency of organizational units named as Decision Making Units (DMUs). This technique compares efficiency of a selected unit (represented with a subscript of o, DMUo) with other units wherein, the efficiencies are calculated by considering the results (outputs) obtained against the resources (inputs) used. Banker and Morey [32] for the first time developed a DEA model capable of considering categorical variables in for efficiency calculations. The DEA model by Banker and Morey [32] is as under:

$$Minimize\ h_0 = Z_0 - \varepsilon\left(\sum_{i=1}^{m'} S_i^- + \sum_{r=1}^{R} S_r^+\right) \tag{1}$$

Such that,

$$\sum_{j=1}^{N} \lambda_j X_{ij} + S_i^- = Z_0 X_{ij0} \qquad i = 1, 2, 3, \dots m' \tag{2}$$

$$\sum_{j=1}^{N} \lambda_j X_{ij} + S_i^- = X_{ij0} \qquad i = m' + 1, m' + 2, m' + 3, \dots, m \tag{3}$$

$$\sum_{j=1}^{N} \lambda_j Y_{rj} - S_r^+ = Y_{ij0} \qquad r = 1, 2, \dots, R \tag{4}$$

$$\sum_{j=1}^{N} \lambda_j = 1 \tag{5}$$

$$\lambda_j \geq 0 \qquad j = 1, 2, \dots, j_0, \dots, N \tag{6}$$

$$S_i^- \geq 0,\ S_r^+ \geq 0 \qquad i = 1,\ 2, \dots,\ m;\ \ r = 1,\ 2, \dots, R \tag{7}$$

In the above model (Equations 1 to 7), we have N DMUs for evaluation, indexed by $j = 1, 2, 3, \dots, j_0, \dots N$. Let us say a DMU consumes i^{th} type of input and produces r^{th} type of output. So, a j^{th} DMU producing r^{th} type of output is denoted by $\{y_{rj} : r = 1, 2, \dots, R; j = 1, 2, \dots, N\}$. Similarly, a j^{th} DMU consuming i^{th} type of input is denoted by $\{x_{ij} : i = 1, 2, \dots, m; j = 1, 2, \dots, N\}$. In the model formulation, constraints 2 and 3 are indexed from *1 to m'* and then from *(m'+1)* to *m* respectively allowing for *m'* manager-controllable inputs and *(m-m')* non-controllable inputs. Variables $S_i^-, S_r^+\ and\ \lambda_j$ are non-negative variables. In the above formulation, categorical variables need to be introduced by changing appropriate constraints. For a categorical input with 5 levels of category (i.e. let's say i^{th} input *m* is categorical with levels as Low, Medium, Good, Very Good, Excellent) constraint equation set 2 needs to be changed. The change needs to be implemented by replacing the following m^{th} linear input constraint from within the set of #2 constraints to the following four constraints. Specifically, this requires replacing

$$\sum_{j=1}^{N} \lambda_j X_{mj} + S_m^- = X_{m,j0} \qquad by$$

$$\sum_{j=1}^{N} \lambda_j d_{m,j}^{(1)} \leq d_{m,j}^{(1)}, \sum_{j=1}^{N} \lambda_j d_{m,j}^{(2)} \leq d_{m,j}^{(2)}, \sum_{j=1}^{N} \lambda_j d_{m,j}^{(3)} \leq d_{m,j}^{(3)}, \sum_{j=1}^{N} \lambda_j d_{m,j}^{(4)} \leq d_{m,j}^{(4)} \tag{8}$$

It must be noted that by the virtue of the above set of constraints, the j_o^{th} DMU ranked as low will take the form as $d_{m,j0}^{(1)} = d_{m,j0}^{(2)} = d_{m,j0}^{(3)} = d_{m,j0}^{(4)} = 0$ and thus the constraint (8) will take the form:

$$\sum_{j=1}^{N} \lambda_j d_{m,jo}^{(k)} \leq 0 \qquad for \quad k = 1, 2, 3, 4 \tag{9}$$

Solving the model with categorical variables (i.e model (1) through (8)) will provide optimal level of efficiency Z_0 (denoted as Z_0*) for the DMU_0. The model needs to be solved *N* times to estimate the efficiency of each DMU_0. Banker and Morey (1986) applied the above model to evaluate the efficiency of 69 pharmacies. In this research, the model is applied to evaluate the efficiency PPPs and traditional project delivery systems using a case study example drawn out from California's Presidio Parkway Project. Special emphasis has been laid to demonstrate the application of DEA models to PPPs to ensure that the model can be modified and used on other similar projects by detailing the steps in Appendix.

4. PRESIDIO PARKWAY ROJECT A CASE STUDY

The Presidio Parkway Project in California, also known as the Doyle Drive Replacement Project, was a $1,969 million PPP project initiated in 2010 (Caltrans [33]). The project aimed to replace an existing 73-year-old south access to the Golden Gate Bridge. The earlier structure reached the end of its design life making it structurally deficient and vulnerable to earthquakes. The project was procured in two phases wherein the second phase was procured as a DBFOM PPP with availability payments. The O&M phase of the project will end in 2043 completing a 30-year concession period. After the concession period, the operation and maintenance responsibilities will be transferred to the public sector (Caltrans [34]).

Developing a DEA model for analysis requires identifying DMUs. Caltrans compared three project delivery methods which will be DMUs in this analysis. The three DMUs are (a) traditional project delivery route i.e. DBB, (b) PPP with financing i.e. DBF, and (c) PPP with all responsibilities transferred to private sector i.e. DBFOM. Next, the input and output factors need to be identified for each DMU. Two project documents, Caltrans [33] and Caltrans [34], were reviewed and one input and six outputs were identified. Capital (i.e. NPV) was identified as input. The project was estimated to incur varying amounts of money when pursued via the DBB, DBF and DBFOM procurement routes. The output factors identified from project documents are a) VfM Over Lifecycle; b) Risk Transfer; c) Cost and Schedule Certainty; d) Use of Public Funds; e) Level of Operations and Maintenance Service; and f) Number of trips. Caltrans was expecting categorical levels of the first five qualitative outputs when pursuing the project via each project delivery method. Caltrans's VfM analysis considered these qualitative factors as critical and the expected suitability of these outputs became the basis of taking the decision to use DBFOM. Hence, in this research we used the same qualitative outputs while considering them on a categorical scale. The number of trips is a numerical output. Just as a manufacturing unit is compared on the basis inputs and outputs, the three project delivery methods were also compared on the basis of one input and six outputs. The project delivery method with low inputs and high outputs is preferred and thus the efficiency-based DEA models are suitable for comparing project delivery methods.

4.1 Setting Up the DEA Model For PPP Projects

In the project documents the five categorical output factors were described using diamond, circle, and square shapes shown in Table 1. These shapes indicated how well the qualitative factors met the project objectives. Square represented best fit, diamond represented average fit and circle represented poor fit. Since these geometrical shapes cannot be used in the model, the factors were translated to a categorical scale varying from 1 to 5. Rating of 1 represents best option, 5 represents most unsuitable option, and 3 represents an averagely suitable project option. As a result, the ratings were obtained as shown in Table 1 for the qualitative outcomes. The qualitative output ratings combined with the quantitative dollar valued NPV and daily trips shown in Table 2 were used for analysis.

Table 1. Qualitative Data from Presidio Parkway Project Translated for Analysis.

Factor	**Description (Source: Caltrans 2010a)**		
	DBB	**DBF**	**DBFOM**
VfM over lifecycle	◇ = 3	○ = 5	□ = 1
Risk Transfer	○ = 5	◇ = 3	□ = 1
Cost & Schedule Certainty	○ = 5	◇ = 3	□ = 1
Use of Public Funds	○ = 5	◇ = 3	□ = 1
Level of O&M Service	◇ = 3	◇ = 3	□ = 1

Table 2. Data for Case Study

DMU	**Numeric Input**	**Categorical Outputs**					**Numeric Output**
	1	1	2	3	4	5	1
	Cost (NPV) $B	VfM over lifecycle	Risk Transfer	Cost & Schedule Certainty	Use of Public Funds	Level of O&M Service	Number of Trips ('000)
DBB	0.635	3	5	5	5	3	120
DBF	0.642	5	3	3	3	3	120
DBFOM	0.488	1	1	1	1	1	120

The data in Table 2 was used to formulate the DEA model which is discussed in detail in Appendix. The DEA model consisting of all equations detailed in the Appendix (from equations (A1) through (A5)) including conditions of non-negativity and unrestricted signs represent the DEA model formulated for comparing DBB with DBF and DBFOM. The formulated example was coded in MS Excel and its Solver (optimization tool) was used to get the results. Similarly, other DMUs are compared against others and relative efficiencies of each DMU was obtained.

5. RESULTS

For the Presidio Parkway Project analysis, the project documents were studied, and the useful information was retrieved. The retrieved qualitative data was translated to ratings ensuring that the ratings reflected the information conveyed through the project documents. Results via Banker and Morey [32] model indicate that DBFOM is the most efficient project delivery option when compared with DBF and DBB. The results are shown in Table 3. As per the Banker and Morey [32] model, DBFOM is the most efficient option getting a relative efficiency score of 1.00, DBB is the second efficient option with a score of 0.7685 and DBF is found to be an inefficient option with a score of 0.7601.

Table 3. Relative Efficiency Scores

Analysis Description	DBB	DBF	DBFOM	Decision
Presidio Parkway Case Study:	0.7685	0.7601	1.000	Use DBFOM, A Validation by Caltrans's decision

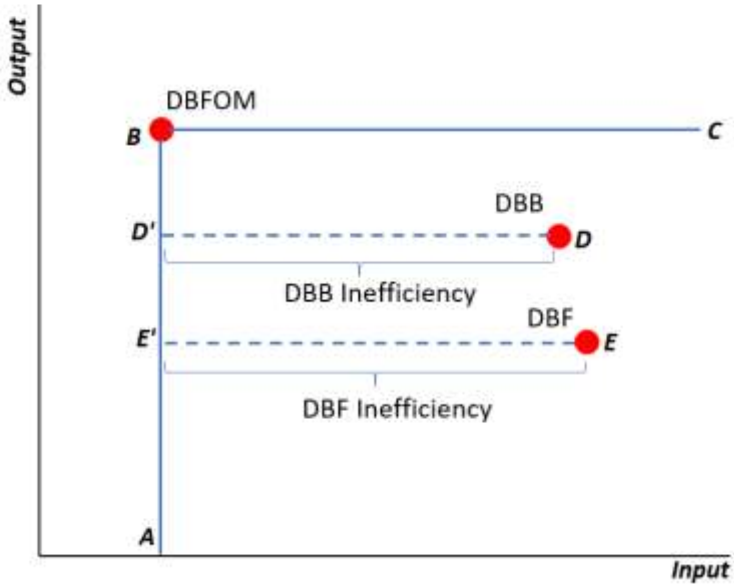

Figure 2. Efficient Frontier for Presidio Parkway Case Study.

The results in Table 3 can be graphically represented as shown in Figure 2. Surface ABC is the efficient frontier for the Presidio Parkway Project. Point B represents DBFOM which was found to be the most efficient DMU when compared with DBB and DBF. The graph shows DBFOM consuming minimum input (Point A) and gives maximum output (Point B′). DBB and DBF are found to be inefficient and they are not on the efficient frontier. DD′ and EE′ represents the inefficiencies in the DBB and DBF project delivery methods respectively. If the inputs consumed by DBB and DBF can be reduced by DD′ and EE′, both the methods will be on the efficient frontier at points D′ and E′. On the other hand, efforts can be made to increase the outputs that will enable the points D and E to find a place on efficient frontier between points B and C.

Caltrans investigated Presidio Parkway project-delivery through DBB, DBF and DBFOM and found that DBFOM was the most efficient project delivery option (Caltrans, [35]). The results obtained from the DEA analysis in this research correctly reflects the actual decision made by agencies and thus validates the results obtained from the DEA model.

6. DISCUSSION AND FUTURE WORKS

In the report by Arup/Parsons Brinckerhoff Joint Venture, the results were conveyed verbally, and geometric shapes were used to show the goodness of fit of each project delivery option for each qualitative factor. As an industry standard, the report subjectively combined qualitative and quantitative assessment outcomes as discussed earlier using Figure 1. The quantitative component was crisp to justify the DBFOM project delivery, but the qualitative component was vulnerable to misinterpretation and thus the overall decision could be ambiguous to many. As per Jahedi and Mendes [36] qualitative scales are easy to misinterpret because these are influenced by biases; are difficult to interpret; and carry no relation between the scale and the facts from the field. The DEAs can help by enabling additional processing of qualitative information to reach an unambiguous efficiency score. The authors of this paper believe that the qualitative scales are unavoidable for PPP related decision-making and ambiguity of qualitative scales make PPP decisions vulnerable. The authors believe that this vulnerability can enable PPP opposing groups to show good projects like the Presidio Parkway Project in bad light leading to litigations. In case of Presidio Parkway Project litigation, the investigations found that the project was procured with due diligence and the procurement was consistent with industry practices (Monk et al [37], Bolanos et al, [38]) but the litigation consumed valuable project time and created doubts in taxpayers' mind about agencies' decision-making capability. The results from this case study analysis not only corroborates Caltrans's decision but also reduces ambiguities that could arise when dealing with qualitative outcomes. In this research the DEA model by Banker and Morey [32] emerged as a supplemental analysis tool that can support PPP section/rejection process.

However, like any methodology, DEA also has limitations. One of the limitations is about limited discriminatory power. If due to any reasons the discretionary power is affecting due to the empirical rule, an alternate approach could be investigated on the lines of Allen and Thanassoulis [39] and Kritikos [40] who used artificial DMUs and Toloo et al [41] who proposed selective modelling approach to overcome the minimum DMU requirement.

6.1 Applying DEAs to Other Procurement Efforts

The analysis conducted in this research was specifically focussed on selecting the most suitable PPP. The process addressed the need to reach an unambiguous efficiency score that can be used to identify the most suitable project delivery methods. However, this approach can be extended to procuring the best suitable contractor, vendor, material, or other project related entity. Each of the procurement decisions have to end at a stage wherein a decision maker has to subjectively combine qualitative and quantitative aspects of the entity. Table 4 shows a few examples wherein the research was conducted acknowledging the fact that the decisions are made by subjectively combining qualitative and quantitative aspects.

Table 4. Procurement Practices with a Possible Application of DEA Models

Sr. No.	**Type of Procurement**	**Details of Subjective Combination**	**Source**
1	Best Value Approach	Points and weighing systems are used in combination with costs for determining best value by States.	Scott et al [42], Tran et al. [43]
2	Contractor Prequalification and Selection	Includes multi-objective decision making. Includes categorical scoring, pairwise comparing, and numerical valued data.	Abudayyeh et al [44], Safa et al [45], Liu et al [46].

While the DEAs have been successfully used in this research, the method is still evolving. Literature review shows that several modifications are made to DEA models to be able to meet the requirements of business unit being evaluated. A review paper by Cook and Seiford [47] includes a comprehensive detail about the evolution of DEAs over the past 30 years. So, with the developing methodology it is anticipate that DEAs will be further enhanced to make them more specific to address many procurement related questions and thus become a mainstream evaluation method when taking decisions based on qualitative and quantitative aspects.

Banker and Natarajan [48] and several other authors have demonstrated using DEAs in conjunction with regression analysis. The regression enables establishing a link between efficiency and other variables that cannot be included in DEA analysis. For example, Banker and Natarajan [48], used the DEA model to first calculate efficiency (referred to as productivity in the paper) from input-output variables followed by regressing them on socioeconomic factors. This enabled determining relation between socio-economic factors and efficiency. However, since the efficiencies are determined using input-output data the second stage regression analysis enables making connections between input-output data and second stage factors. Earlier, Ray [49] had conducted the two-stage analysis on schools in Connecticut. During the first stage the DEA efficiency scores were determined for three inputs (number of teacher per student, number of support staff, and administrative staff per student) and four outputs (score obtained in mathematics, score obtained in arts language, writing score, and reading score) from 122 district schools. The DEA analysis enabled obtaining the efficiency of the 122 schools. These efficiency scores were then considered as dependent variables while seven other socioeconomic variables were considered as independent variables for regression analysis. The independent variables included (i) parental education, (ii) per capita income, (iii) value of owner occupied housing units, (iv) percentage of students from minority groups, (v) percentage of students receiving financial aid, (vi) percentage of families in low income group and (vii) percentage of children coming from single-parent families. The regression analysis enabled a more holistic understanding of the schools' efficiency. The two-stage analysis enabled understanding that the schools that had low efficiency were impacted by the socioeconomic factors of the district. A very similar two stage analysis can be conducted with DEA analysis in the first stage while considering PPP related input-output and then in the second stage regression analysis considering socio-economic factors associated with transportation projects. The analysis is expected to provide useful insights for policy and decision makers for developing PPP related policies.

7. RECOMMENDATION FOR IMPLEMENTING DEA MODELS FOR REAL-LIFE PPP PROJECTS

Following is a list of steps that can help agencies to adopt DEA models for supplementing current practices:

(1) Acquiring Data: The data required to conduct DEA analysis can be retrieved from VfM assessment and supplemented with expert opinion. In case of differences in expert opinions, proven techniques such as Delphi method can be used to reach consensus. Agencies can develop questions similar to the set shown in Table 5 for eliciting expert opinion. The questions shown in Table 5 are for DBB project delivery considering the output factors used in Presidio Parkway Project. Similar questions can be developed for other project delivery methods and for other projects.

Table 5. Questions for Rating the Factors Affecting Project Delivery Efficiency

Factor	**Questions For DBB Project Delivery**
VfM over lifecycle	How effective will be the DBB route to provide VfM over lifecycle?
Risk Transfer	How effective will be the DBB route in terms of Risk Transfer?
Cost & Time Certainty	How effective will be the DBB route in ensuring Cost & Time Certainty?
Use of Public Funds	How effective will be the DBB route in Utilizing Public Funds?
Level of O&M Service	What is the Level of O&M Service using DBB route?

(2) Converting Qualitative Data to Ordinal Scales: The data obtained from experts can be converted to appropriate ordinal scale. A simple ordinal scaling system can have "Excellent Fit" ranked as 1; "Very Good Fit" ranked as 2, "Good Fit" ranked as 3, "Average Fit" ranked as 4, "Bad Fit" ranked as 5, "Very Bad Fit" ranked as 6 and "Extremely Bad Fit" ranked as 7.

(3) Number of Input-Output Factors: In this research, the DEA model was used for one input and five outputs. However, the same DEA model can be extended to integrate many other inputs and outputs.

(4) Inferential Information: Sensitivity analysis using perturbed data can help identify factors that influence project outcomes more than others. The information can be used to concentrate agency's focus on factors that can help the project succeed.

(5) Reducing Chances of Litigation: DEA is an advanced linear programming model. Using such mathematical tools will help in increasing transparency and reduce the chances of future criticism and litigation of PPP projects.

(6) Adoption by Agencies: The analysis can be easily conducted using MS Excel's inbuilt Solver. Excel being one of the most commonly used tool the DEA models have a potential of a quick adoption by decision makers.

(7) Training Decision Makers: An Excel based toolkit can be developed to train professionals and to standardize its use across various transportation agencies.

8. CONCLUSION

PPPs are considered as mainstream project delivery systems in many developing and developed countries around the world, but in the US the PPPs are relatively new and are not exploited fully. Some of US projects were criticized and some of them were challenged in courts. PPPs are investment intensive projects and when such projects are criticized and challenged, it maligns public sector's decision-making capabilities and jeopardize the success of future PPPs. This is a concern for government agencies because the decisions for these projects are representative of agencies' decision-making capability, diligence and accountability. Through this research paper, application of a DEA model is demonstrated to improvise the existing decision-making processes.

In general, the results of this research show that DEA models can be used to support decision-making efforts covering different type of PPPs. This was illustrated by customizing DEA model for California's Presidio Parkway Project which yielded expected results and corroborated the suggestions by Arup/Parsons Brinckerhoff Joint Venture consulting team. One of the most important finding from the analysis can be drawn from the fact that the DEA model was able to mathematically supplement intuitive decision, which will strengthen the test of legality if challenged in courts. Another unique feature of DEA model is that the model allows integrating quantitative factors with qualitative factors to reach a unified efficiency-based outcome that will also reduce the risk of unnecessary litigation. This paper includes minute details about developing equations for DEA model for PPPs which will help decision makers to use the model on PPP projects. Since the DEA methodology is relatively new (Cook and Seiford [47]), more advancements in the model are expected to refine the model performance and results. Based on the overall results, use of DEAs have the potential of application on PPP projects as a supplemental analysis tool. The paper enlists several steps to help agencies adopt DEAs for decision-making.

Based on the research findings, it is expected that agencies will be able to adopt DEA model framework for analysis and strengthen their existing decision-making processes. Future decision makers and researchers will be able to build upon this work by exploring the application of similar DEA models on traditional and other innovative project delivery methods. Many other procurement related decisions are based on qualitative and quantitative components and hence we recommend investigating the applicability of DEA models to related problems in procurement. In the future, developing a computer based toolkit is expected to reduce modelling complexity and make the DEAs user friendly.

CONFLICT OF INTERESTS

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