

Managing Complex Projects: A Case Study on Emission Inventories & Air Quality Analyses

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Government organizations have faced difficulties in delivering services related to environmental quality and engineering. One of the most pronounced issues has been the inability to clearly define project requirements and quality expectations. The Best Value Performance Information Procurement System (BV PIPS) is a high performing delivery system that moves the responsibility of identifying project requirements to the vendor instead of the owner. The Arizona Department of Environmental Quality (ADEQ), Sustainability Programs Unit (SPU) identified the BV PIPS model as a potential solution to their environmental project performance issues. ADEQ identified an air quality project, the Yuma PM10 Emission Inventory, to test the BV PIPS model to verify if it could improve the performance of their environmental projects despite their inability to clearly define a scope of work. This paper documents the ADEQ's implementation of BV PIPS on the Yuma project. The results show that in comparison with a past ADEQ emissions inventory, this project has shown to greatly decrease the overall cost and schedule deviations by 65% and over 300% respectively with a client satisfaction of 10 out of 10.

Key Words: Best Value, scope, project management, pre-planning, environmental engineering

Introduction

Environmental quality and engineering services have experienced poor performance and low customer satisfaction. The Independent Evaluation Group (IEG) has closely tracked the performance and satisfaction ratings of over 10,000 World Bank funded projects, spanning 30+ years (IEG, 2013). Of all IEG analyzed projects, 54% were completed with satisfactory results according to IEG standards. Environmental projects are among the lowest performing with only 39% of the total projects having satisfactory results. The World Bank defines environmental projects as any that manage, gather, or safeguard large natural resources (water, oil, air, flora, etc). Over the past century, some of the most costly, unsuccessful (high cost and schedule deviations) construction projects have come from the environmental sector. A few examples include: *Three Gorges Dam* – $29B cost deviation (Fu et al., 2010; Rueters 2009), *Lesotho Highlands water project* – $17B cost deviation (International Rivers, 2005), *Venice Flooding MOSE Project* – $6.4B total cost deviation (Sood, 2011), *Panama Canal Expansion* - $737M cost deviation (AFP 2014), and *Office du Niger, Mali water management* – $300M total cost without completion (Filipovich, 2001).

Cost deviation and project failure is present in all sectors of construction and service delivery, but it is often more prevalent in environmental projects (Esty & Porter, 2005). Environmental projects are complex in nature. At the beginning of projects there is important information missing to accurately determine the requirements needed to achieve the desired outcome. Current research has found that environmental projects have complex scopes due to the large variability of data and environmental contributing factors (Esty & Porter). The environmental analysis component of typical construction projects significantly contributes to project cost due to its complexity (Macek, 2006). Environmental

project failure and large cost deviations are largely due to a lack of data and complex or ill-defined project scopes (Fisher, 2013; Buntaine & Parks, 2013).

The Arizona Department of Environmental Quality

The Arizona Department of Environmental Quality (ADEQ) is the environmental regulatory agency for Arizona, covering a population of 6.8 million people. ADEQ today administers a variety of programs (air quality, water quality, waste management), to improve the health and welfare of its citizens and ensure that the quality of Arizona's air, land, and water resources meet regulatory standards. With over 450 employees managing various contaminants and pollutions, ADEQ strives to lead Arizona and the nation in protecting the environment and improving the quality of life for the people in the State of Arizona. In 2014, ADEQ was not satisfied with the performance of their environmental professional services. The upper management at ADEQ identified that they were unable to select the high performing environmental experts that met the quality expectations of ADEQ. They also identified their resources were not being fully utilized. ADEQ was unable to accurately define a scope of work for their environmental projects. ADEQ has identified that the lack of information has forced them to make blind decisions on projects. As a result, the vendors cannot be held accountable for non-performance due to ADEQ mandates and regulations. ADEQ is faced with the same problem as many other environmental agencies; namely, an inability to define a scope of work for complex projects.

Problem

Current industry project management methodologies and delivery methods have failed to yield consistently high performing (on schedule, on budget, and high satisfaction ratings environmental engineering projects. The nature of environmental projects is complex due to the large data analysis requirements. Traditional industry models require the owner to have an accurate set of requirements when contracting with a vendor. These requirements form the basis for a project scope. The owner needs accurate requirements for two reasons: one, vendors are selected for a project based on how well they meet the requirements and two, owners contract with vendors in order to meet an objective outlined by owner requirements.The basis of all traditional construction and service delivery projects is based on project requirements and scope. Requirements are established in order to help meet a desired outcome. If an owner creates an inaccurate requirement, they may select an underqualified vendor and require the vendor to perform the wrong requirement, which will result in an undesirable project outcome. If the owner is unable to come up with requirements, they cannot select a vendor using traditional methodologies because they have no way to accurately evaluate a vendor’s capability to achieve project goals. In the case of environmental engineering and services, projects are too complex in scope and methodology. To determine the scope of an environmental project requires extensive data analyses (Jakeman, et. al., 2006). When owners lack the resources or the expertise to perform these analyses, they cannot create an accurate project scope or set of requirements.

High project complexity and low performance is not exclusive to the environmental engineering industry. A complex project can be seen as any project with a difficult-to-define scope of work. The construction industry, in particular, is challenged with low global project performance. In the 2011 construction projects in the UK were still only completing on time 45%, and met budgets by up to 63% (UK Report 2011; Kashiwagi, 2013). Construction companies have the second highest failure and bankruptcy rate of 95% (Associated General Contractors, 2006). 2.5% of projects are defined as successful (scope, cost, schedule, & business), 25 to 50% is wasted due to coordinating labor on a project, and management inefficiency costs owners between $15.6 and $36 billion per year (Lepatner, 2007; PWC, 2009; Yun, 2013).

Best Value Performance Information Procurement System

Best Value Performance Information Procurement System (BV PIPS) is a methodology developed precisely to address the issues of industry complexity and low performance. BV PIPS has been tested in the entire supply chain (construction and non-construction services). Its developments have been researched and developed in support of professional groups like the International Council for Building (CIB) and the International Facility Management Association (IFMA) for the last 23 years, and has been identified as a more efficient approach to the delivery of professional services.

Some of the impacts of the PIPS are as follows (Kashiwagi, 2013; Rivera, 2014; PBSRG, 2015):

- Developed (1992-present) at the Performance Based Studies Research Group (PBSRG) at Arizona State University (ASU). PBSRG has received a total of $15.9 million in funding with over 313 grants.
- Documented performance of over 1800 projects or $6 billion (1629 projects, $4B construction and 89 projects, $2B non construction), customer satisfaction of 9.8 (out of 10), 93.5% of projects on time and 96.7% on budget.
- Research tests show that in procuring of services outside of construction, the observed value is 33% or an increase of revenue or decrease in cost of 33% (Kashiwagi, 2013).

BV PIPS Methodology

BV PIPS is a practical solution aimed at delivering high performing projects and services even when up-front project information is deficient or complex. The model allows a client to select an expert vendor based on their past performance metrics and their ability to identify and mitigate risk. BV PIPS creates a structure in which the owner does not manage, direct, or control the vendor, and the vendor is viewed as the subject matter expert. In this system, the owner and end user define a list of minimum project requirements and the expert vendor is responsible for creating the project plan and objectives. The system is divided into three functional phases: selection, clarification, and execution. The purpose of each of these phases is to ensure that: an expert vendor is selected, the vendor can create a simple project plan that the client understands, and the vendor is held accountable for the performance and delivery of the project.

BV PIPS allows a client to run a project without defining a scope of work or undergoing detailed preplanning. When an expert vendor is properly utilized, there is no need for an owner to create a list of technical project requirements. The expert vendor creates a plan to execute the project, identifies the key areas of risk, and tracks performance metrics in order to hold themselves accountable for the outcome of the project. Under this system, the client no longer needs to take risks by making decisions and telling the vendor what to do. The significance of the BV PIPS system is that it focuses primarily on the high level organizational structure of the supply chain instead of detailed functional processes. Because of this, BV PIPS is flexible and can translate to a variety of industries and project types. The past performance of BV PIPS suggests that BV PIPS can yield high project performance despite project complexity. This also further supports the claim that BV PIPS can be implemented on projects from any industry, specifically construction and environmental engineering. The value of BV PIPS is the same across any industry; it yields successful project outcomes without requiring the vendor to define a scope of work.

Proposal

BV PIPS is used to mitigate the risk and increase the performance of traditional construction projects and highly complex services. The authors propose that the BV PIPS methodology can address the same issue of high complexity in environmental engineering. In order to measure the viability of BV PIPS in environmental engineering and services, ADEQ will run a test case to see if the BV PIPS can produce similar high performance results as it has in construction and information technology.

Methodology

ADEQ is seeking to increase the performance of their environmental projects by implementing BV PIPS. ADEQ is conducting a test case of BV PIPS on an air quality analysis project in Yuma County, Arizona. In order to measure the effectiveness of BV PIPS, the following methodology will be implemented:

1. Identify how the BV system is able to deliver a project without knowing all project information and constraints at the beginning of a project.
2. Establish a traditional baseline. Identify a past air quality analysis project similar to the Yuma project in scope and objective.
3. Document the implementation of BV PIPS on the Yuma project and track the performance.
4. Compare the results of the Yuma project to the traditional baseline.

Traditional Project Delivery Methodologies

In a traditional procurement process, the client assumes that they know what is best for the project since they are paying for the service. The client typically defines a scope of work and selects a vendor who can address the scope at the lowest cost. For ADEQ the traditional system is divided into four functional phases:

1. *Preplanning*: The client end-user creates a scope of work which contains a list of technical requirements and sends it to procurement. Procurement creates a request for proposals (RFP) based on the scope of work.

2. *Vendor Bidding*: Vendors will respond to the RFP by submitting a bid proposal. In their proposal, vendors report on their experience, technical capabilities, company background and financials, project scope and cost, and background of key individuals.

3. *Evaluation*: The client procurement team reviews the bid proposals and classifies them as: responsive, non-responsive, and no bid. The responsive proposals are sent to an evaluation team who then rates each section. If needed, interviews and negotiations are conducted with all potential vendors.

4. *Award*: Once the evaluation team selects a vendor, procurement will approve and create the final contract. The contract will consist of a list of technical requirements that the vendor is responsible to accomplish. The vendor will sign the final contract and the project will commence. After commencement, procurement is no longer involved.

Delivering Projects with the BV PIPS

The purpose of BV PIPS is to simplify the procurement process. BV PIPS eliminates the need for technical information and thus allows a non-expert client to select an expert vendor. The process assumes that the client has little to no knowledge about the project scope. This fact is the very reason why clients seek to hire vendors; the client is not fully qualified to complete the work using their own means. The BV PIPS methodology uses a similar basic structure as the traditional procurement process, but works to decrease client involvement and management while increasing vendor involvement and guidance. Using BV PIPS, ADEQ adjusted their system to four alternative functional phases:

1. *Pre-Qualification*: The RFP is published without a technical scope of work. The RFP includes a list of client high level expectations (i.e. Customer must be satisfied with work, Work should meet all

legal requirements and regulations, etc.). Qualifying vendors submit their bid proposals. In their proposals, vendors use their past performance metrics to identify: their project capability or expertise, risk assessment of the project, and any value added options. The vendor is never asked to submit any technical information, just simple justification for why they should be hired.

2. *Selection*: The client assembles a team of project professionals to evaluate the bids. Vendor names, personal information, and cost are removed from the bids to ensure non-biased blind evaluations. Each section of the vendor responses are rated on their simplicity and use of non-technical past performance metrics. The vendor's goal is to provide justification for why they are an expert, and clearly identify any areas of risk and potential solutions that could impact the project. The evaluation team then interviews the highest rated vendors. The key project personnel from each vendor are asked to describe the project from start to finish using non-technical terms and describe the areas of risk. The most qualified vendor is able to simply describe a project scope and execute the project within the client's budget.

3. *Clarification*: The selected vendor creates a detailed project plan which includes a scope of work, milestone schedule, cost breakout, and a risk mitigation plan. In order to ensure the client is comfortable the vendor identifies all risks (events that could occur that could change their base plan) and identifies when it could occur and the potential impact. This shows the value of using expertise, as the vendor without any information knows what could occur due to their experience. Thus, the client is not surprised at any events that might occur. The client then meets to let the vendor know of any concerns they have with the plan. The vendor must resolve any client issues before they are awarded the contract. If the client finds that the vendor cannot resolve their concerns, then the vendor is dismissed and the client selects the next highest rated vendor.

4. *Execution*: The evaluation team approves the vendor's project scope, and sends it to procurement. Procurement writes the contract based on the project scope. The vendor executes the project and submits a weekly performance report that updates the client on project schedule and performance metrics. If ever the weekly report causes client concerns, additional clarification meetings are scheduled. Although the overall BV PIPS process is similar to the traditional procurement methodology, BV PIPS makes several unique changes to select the most qualified vendor and ensure high project performance. The methodology changes are as follows:

    1. The project baseline is established using a previous project's past performance.
    2. The RFP includes a list of minimum requirements instead of a technical scope.
    3. Vendors provide past performance metrics to justify their level of expertise and ability to mitigate risk.
    4. Only the vendors' project professionals are interview instead of a marketing or sales team.
    5. Vendors are evaluated on their level of expertise and not price.
    6. The vendor outlines the project execution plan, risk mitigation plan, and defines the desired outcomes.
    7. Before the contract is signed, the client is given an opportunity to approve the vendor's plan.
    8. The contract is defined using the vendor's schedule and project outcomes.

Establishing Case Study Baseline

The projects under investigation are air quality PM_{10} emissions inventories conducted by ADEQ. A past project, the Pinal County project, was implemented in 2006 using a traditional low-bid procurement methodology and project management system. The Yuma project was implemented in 2015 using the BV PIPS methodology. As shown in Table 1, both projects are similar in nature; sharing a comparable projected, schedule, geographic area of work, and objective. The primary difference is that, in the Yuma

project, vendors were also asked to conduct an analysis of ambient air quality from 2006 to 2014, thus resulting in two extra months in the project timeframe.

Table 1

Comparison of Pinal County and Yuma County Projects

Criteria	Pinal	Yuma
Timeframe (months)	6	8
Geographic Area (square miles)	5,374	5,519
Pollutant Under Examination	PM_{10}	PM_{10}

Implementation of BV PIPS on the Yuma County Project

During the pre-qualification phase, ADEQ participated in several education sessions in order to prepare them to implement BV PIPS. They were required to revise their RFP in order to eliminate any technical requirements and re-write it to explain BV PIPS evaluation methodologies.

In the selection phase all vendors were given the opportunity to justify their level of expertise to ADEQ. The vendor reported on three categories: their ability to meet the project objective (project capability), their ability to identify and mitigate risk (risk assessment), and any services or products they could provide to improve the project outcome (value added). The most qualified vendors (A, B, and C) sent their project managers to interview with ADEQ wherein ADEQ evaluated their expert's ability to create the project scope. The final results of the selection phase are shown in Table 2. The highest performing vendor was Vendor A.

Table 2

The Results of the Section Phase Evaluation

Criteria	Weight	Vendor A	Vendor B	Vendor C	Vendor D (Eliminated)	Vendor E (Eliminated)
Project Capability	20	7.5	7.5	8.8	5.0	5.0
Risk Assessment	15	8.8	7.5	6.3	6.3	4.0
Value Added	10	8.8	6.3	8.8	4.0	5.0
Interview Rating	40	8.8	6.9	6.4	0.0	0.0
Cost	15	$ 93,744.50	$109,150.30	124,000.00	$121,060.00	$ 94,000.00
TOTAL SCORE:		**97**	**81**	**81**	**39**	**38**

Initially, the owner chose Vendor A to move onto the clarification phase. After establishing the project plan according to BV PIPS methodology, ADEQ identified that Vendor A was unable to meet the project requirements within the bounds of the project budget. Vendor A was dismissed and Vendor B moved to the clarification phase. Despite having the same evaluation score, Vendor B was chosen over Vendor C

because their interview rating was higher. Vendor B identified in the interview steps that should be taken that no other vendor identified. These steps ended up being very critical to project success. Vendor B created a detailed milestone schedule, a cost breakout, and risk mitigation plan. The vendor identified major risks that could occur due to a lack of information that could only be found through extensive investigation. The vendor also identified exact solutions to minimize these risk if they occurred. This enabled ADEQ to feel comfortable with signing a contract, despite not knowing everything that would be required on the project.

In the execution phase, the selected vendor carried out the project according to the scope and milestone schedule that they defined in Phase II. Throughout the course of the project, the vendor tracked and reported on performance and progress of project tasks on a weekly basis. This enabled ADEQ to keep the vendor accountable and monitor the project without using management, direction, and control. Due to the vendor pre-identifying potential issues during clarification, the client was not surprised by any deviations to the project, as they were foretold the probability of them occurring upfront.

Performance Comparison

The Pinal County project and the Yuma County project differed greatly in their scope of work (SOW). The key differences are as follows:

1. The first section of the Pinal SOW included a list of regulations and requirements that had to be met.
2. The Pinal SOW did not included a cost breakout for each item.
3. The Pinal SOW estimated general dates for each phase of the project, whereas the Yuma SOW provided exact dates for each deliverable.
4. The Yuma SOW described each deliverable using performance metrics.
5. The Yuma SOW provided a staffing plan which included estimated project roles and hours.
6. The Yuma SOW only provided technical information in the appendices, whereas the Pinal SOW included technical information throughout the entire document.

After the completion of the Yuma project using the BV PIPS methodology, the authors compared the project results to the previous performance of the Pinal project. The projects are compared based on the performance of the procurement process (see Table 3) and the overall project delivery performance (see Table 4). Each table includes a difference column which calculates the percent difference where E_1 is the Yuma value and E_2 is the Pinal value:

$$\%\ Difference = \frac{|E_1 - E_2|}{\frac{1}{2}(E_1 + E_2)} \cdot 100$$

Figure 1 – Precent Difference Formula

Table 3

Comparison of Procurement Process Performance

Criteria	Unit	Pinal	Yuma	Difference
Size of Vendor Proposals	pages	31	18	53%
Proposal Evaluation Timeframe	hours	16	2	156%
ADEQ Satisfaction Rating	(1-10)	6.33	8.3	27%

Administrative Cost	$	$ 2,400.00	$ 300.00	156%

In comparing the performance of the procurement process, Yuma is shown to have significantly greater results. Procurement for the Yuma project required less time and effort from both ADEQ and the vendors. ADEQ was more satisfied with the procurement process overall, and saved over $2,000.

Table 4

Comparison of Project Delivery Performance

ADEQ Criteria	Pinal	Yuma	Difference
Total Cost of Projects	$400K	$138K	97%
Overall Client Satisfaction	3/10	7/10	80%
Project Duration (days)	730	366	66%
% Total Schedule Deviation	150%	25.77%	141%
% Cost deviation	300%	0.5%	143%
% of Milestone Deliverables Requiring ADEQ Revisions	100%	0%	200%

As shown in Table 4, the Yuma project has a significantly greater project delivery performance than the Pinal project. Overall, Yuma required less time (141%), had a lower cost (97%), required less support from ADEQ (200%), and had a higher client satisfaction rating (80%). The schedule deviation on the Yuma project was a result of ADEQ changing their management team and requesting a two month hiatus on the project, thus the delay was the fault of the client and not the vendor. The Yuma cost deviation was a result of unforeseen regulatory changes made by the federal Environmental Protection Agency who holds the authority of all environmental air quality regulations.

Conclusion

Environmental engineering projects and services are under performing compared to other industries. Due to the highly complex nature of environmental analysis, the industry is hard-pressed to accurately define project requirements and scopes ahead of time. As a result, many owners will make inaccurate estimations and decisions based on what they believe to be correct therefore skewing the scope of the project from the get-go. The challenge owners are facing now is how to deliver high performance projects without clearly defining a project scope. The Best Value Performance Information Procurement System (BV PIPS) utilizes the expertise of a vendor to create a non-technical project delivery plan, thus enabling owners to execute more complex projects and eliminate the need to define a technical scope of work. An expert vendor can outline a project from start to finish and identify any areas of risk. This enables a client to understand the high level process of the project without needed to understand any of the technical details. In allowing a vendor or contractor the freedom to define the project scope, the client or owner can maintain high project performance without needing to make estimations or decisions.

In a case study with the Arizona Department of Environmental Quality, it has been shown that in using BV PIPS, projects can be delivered without needing a clearly defined scope of work. Furthermore, an ADEQ project delivered using BV PIPS shows significantly greater project performance (schedule, cost, satisfaction) than a traditionally procured project. BV PIPS enables owners to minimize cost and schedule deviations of projects that do not have a defined scope of work. This case study suggests that maintaining high performance on complex projects is possible in any industry when the vendor is given freedom to define the scope of work with being managed, directed, or controlled by the owner. In this way, the

methodology implemented at ADEQ could be translated to work for construction projects. The major limitation being organizational inertia, or resistance to implementing a new and unknown methodology.

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